The Relation of Five Major Hill Vegetation Communities to Soil Type and Conditions in South-East Scotland.

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C o n t e n t s

INTRODUCTION

The relation of plant-life to its environment has in the past been the basis of extensive investigation and the student of natural vegetation recognises that a given environment is typified by a distinctive plant or association of plants. There are three aspects to ecological research which, though ultimately indivisible, may for the purposes of definition be considered separately. These are, firstly, the plant species themselves; secondly, the environment; and thirdly the relation of each to the other. The term "environment" itself, covers four main factors. There is the climatic factor which includes all the effects of the external atmosphere on the plant; there is the physiographic factor which concerns the geographical location of the habitat of the plant in relation to its growth; there is the biotic factor which is the effect of animal and human life on plant distribution; and there is the edaphic factor, or the influence of the soil on the growing plant. In this study, the main emphasis is on the edaphic factor, though its relation /

relation to the other three must not be overlooked. "Environment", therefore, must be held to refer more generally to the conditions resulting from the interaction of all four. It is thus only under very favourable or specialised conditions that it is possible to relate plant growth to any one environment-al factor.

Ideally, this study presupposes a natural, virgin vegetation such as may be found in the unpopulated regions of the world. In Britain, however, this condition is virtually unattainable and an area must therefore be selected where the biotic influence is least operative, or where the form of disturbance of the natural state is known and has been fairly constant over a considerable period of time. In the Southern Uplands of Scotland, the breeding and rearing of sheep has been traditional for many centuries, and the hill-land, apart from the changes brought about by the grazing habit of sheep, is thus "natural" vegetation. There are, of course, other disturbances which may be held as relatively unimportant: A few cattle are run on the hills in Summer, and round the few farms, land has been enclosed and put under arable cultivation. More recently, a few areas have been afforested. We may however, reasonably assume that this type of country is as near the natural state as any other that can be found /

found in Britain. For this reason, the investigation was carried out on Sourhope Farm in the Cheviot Hills.

The object of this study is to ascertain whether there are any differences, chemical or physical, in the composition of soil which supports typical communities of hill species such as are found naturally on Sourhope Farm; and secondly, whether these differences are such as to allow a definition of habitat for the various plant communities. At the outset, it was appreciated that an exhaustive examination of a circumscribed area would ultimately yield more rewarding information than of widely scattered centres. With the exception, therefore, of the Calluna vulgaris vegetation which is poorly represented, the majority of results are derived from samples taken within the boundary of the Farm itself. To allow a fair comparison of results the areas selected for Calluna vulgaris were considered as typical of the Cheviot Hills.

A further advantage to be gained by confining the examination of soils to a small acreage is, firstly, that climatic differences are reduced, and secondly apart from one small intrusion and a few dykes, the parent rock is similar throughout the area. Glacial deposits are present but these are confined to the lower slopes and valleys

and /

and are, according to the Survey, locally derived from the parent Andesitic lava.

Situation:

Sourhope Farm is situated seven miles from Yetholm in the Cheviot Hills at the head of Bowmont Water. On the west side, the farm marches along the Scottish-English border and overlooks the College Valley in Northumberland. With the addition of the smaller farm of Auchope, it is enclosed by a horse-shoe of hills open to the south-west. It is drained by two small streams and their tributaries, the Sourhope Burn flowing south-west and collecting water from the hills to the West and North, and the Kaim Burn flowing West draining the hills to the East and South. The actual steading is situated at the confluence of these two streams from which the combined waters flow to join the Bowmont Water at the Farm's South-western boundary. The farmhouse occupies the lowest ground and stands at a height of 750 feet. On the Eastern march, the land rises to 2,000 feet at the summit of The Schil. Approximately,25% of the land is below 1,000 feet, 50% between 1,000 feet and 1,500 feet and the remaining 25% is over 1,500. In the centre of the basin, the Fasset Hill, dividing the courses of the Sourhope /

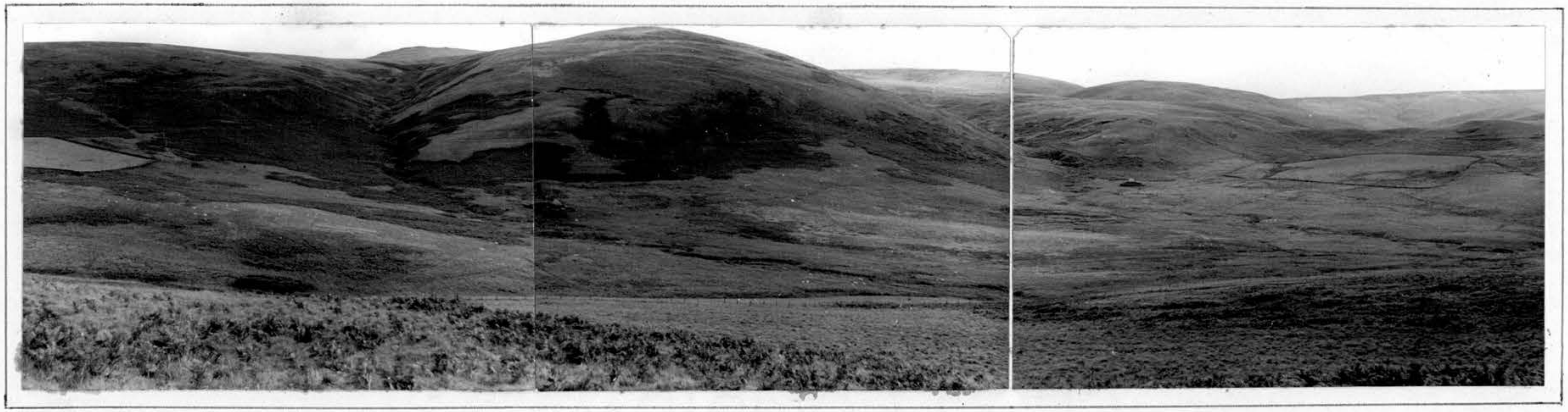

Photo. 1.

Panorama of the Rigg, Dod Hill and Gairs. Note the sparse bracken in the foreground and the denser margins of the bracken patches on the lower slopes of the Dod.

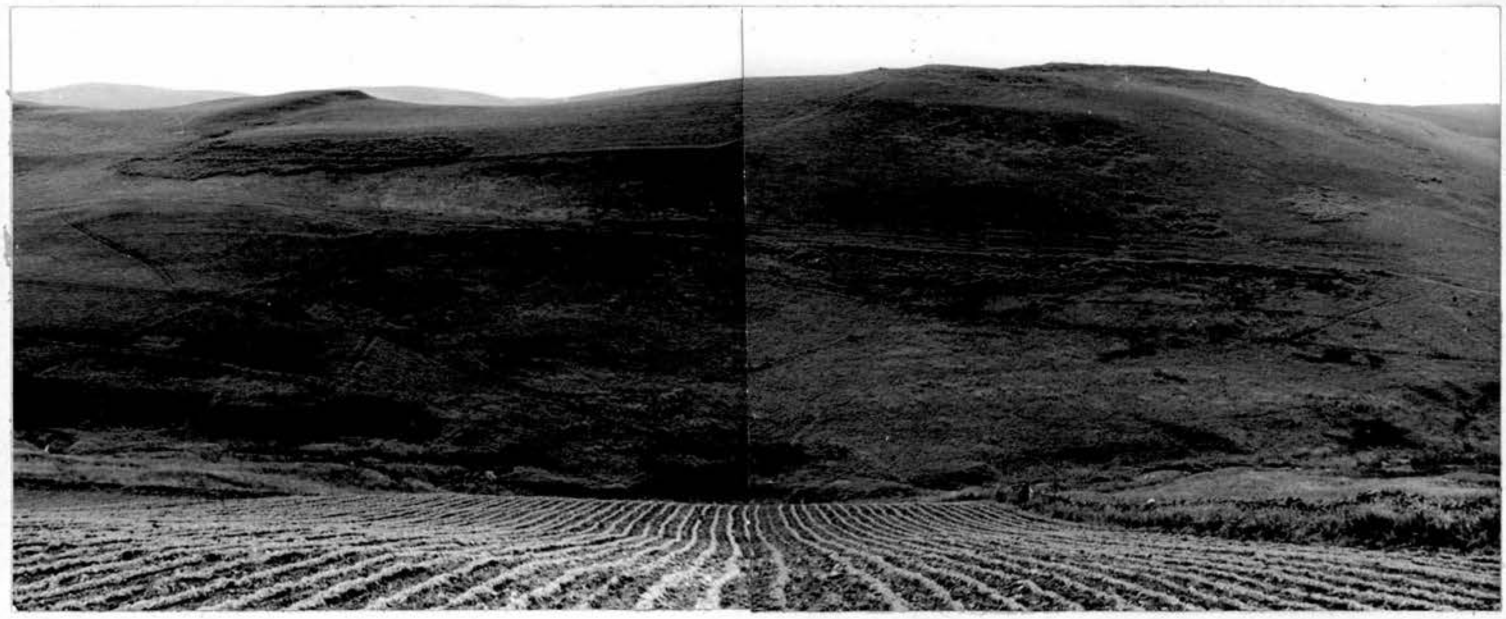

Photo. 2.

The north face of the Park Law. The track running horizontally across the centre of the photograph is the approximate spring line. Above this line is Molinia grading into a Deschampsia flexuosa community on the steep brow. Below the spring line the vegetation is of a rough Agrostis-Nardus type.

Photo. 3.

The north-west face of Fasset.

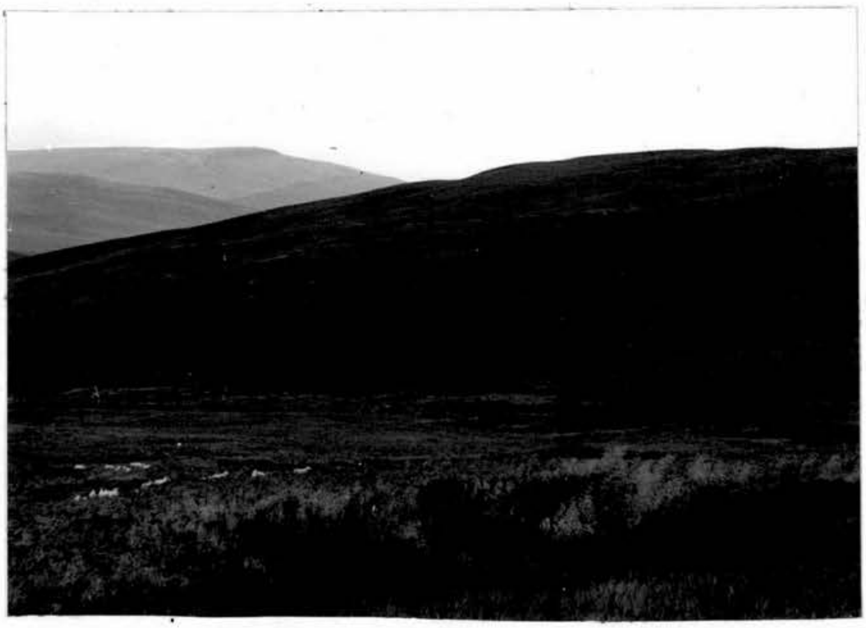

Photo. 4.

South-west face of Fasset.

Photo. 5.

South-west face and summit of the Schil.

Photo. 6.

South-west face of Hairny Law.

Sourhope and the Kaim Burns, rises to just over 1,000 feet. North-west and North of the Farm are the Hairny Law and Shorthope with a maximum elevation at Blackdean Curr of 1,500 feet. To the East, the Birnie Brae and the Dod Hill rise above 1,500 feet. To the South is the Park Law of just over 1,D00 feet. All these hills are of the characteristic South Upland type, steep sided and round-topped with a complete vegetation cover and few outcrops of rock. (See Photos. 1, 2, 3, 4 and 5 & 6) The small burns and sikes which drain them have deeply cut narrow valleys, and descend rapidly into the larger streams on lower ground. Springs and flushes are frequent and some of the hills show a clearly defined spring line. The main streams run in broad, flat-bottomed valleys, probably much enlarged by ice action. Floods and spates are common as a result of the speed of the run-off from the catchment area.

The locality is not without its archeological interest: On the summits and knowes are forts and earthworks of Cambro-British times. On Park Law there is a very large earthwork from which turf walls radiate to enclose most of the surrounding flat ground on the summit. (See photo. 2). The large man-made cairn on The Schil is another relict of these early settlements. It has been suggested that these works /

works would have been constructed above the original forest margin but today, the area is completely treeless.

The Farm has a total area of 3,000 acres of which 100 acres are under arable cultivation. The main crop is hay for winter feed for sheep and cattle, though a little rotational oats and turnips are grown. The lateness of the season, the Spring droughts and the September rain make, however, the harvesting of oats uncertain. The main livelihood of the Farm derives from its stock of Cheviot and Blackface sheep, with the addition, more recently, of Blue-grey cattle, grazed on the hill. In recent years, some hill land has been enclosed, ploughed and reseeded in an effort to raise the arable acreage for the production of winter keep.

<u>Soils</u>:

In 1949, a soil survey of Sourhope Farm and of the surrounding countryside was carried out by the members of the Scottish Soil Survey. The following information was obtained from their report, and from the Soil Survey of Great Britain, Report No. 2.

The soils of the Farm are part of the Sourhope Association of Soils and have been formed from pinkish-brown till derived from /

from porphyritic lava of Old Red Sandstone Age. Within the Farm boundaries, there are found two main associations; these are termed the 'Sourhope' and 'Fasset' associations, and are differentiated as follows:-

Sourhope Association:- on the lower slopes are clay to clay-loam tills with a mull A horizon. Drainage is generally poor and the vegetation ranges from an Agrostis-fescue type on the drier parts to a Juncus communis--Deschampsia caespitosa ~~flexuosa~~ on the wetter. On the upper slopes of the same soil association, a range of soils is developed on a shattered residual, porphyritic lava and pockety, stony-loam till. The slopes are usually steep and the vegetation is dominated by Agrostis-fescue and a short Pteris aquilina type.

Fasset Association:- this range of soils is developed on the flattish hill tops and is of a podsolic type. Mor humus is present and occasionally an iron pan. The parent soil is a stony loam till. Two main vegetation types characterise this association. In the drier parts, these are Nardus-Molinia-Polytrichum, and in the wetter, Calluna-Juncus squarrosus and Sphagnum Spp.

The peat on the Farm may be divided according to depth, each carrying its characteristic growth.-

(1) Less than two feet - carrying Nardus.

(2) Cut-over peat carrying Calluna and Eriophorum.

(3) Deep peat (over two feet) carrying /

carrying Calluna and Eriophorum.

The soils map of the Farm (Map 1, page 83.) shows the distribution of these associations, and seven soil types have been identified in all. Each soil type is further subdivided into two to four members.

Thirteen profiles were taken during the course of the survey, reference to which will be made at a later stage in this work.

Climate:

By virtue of its position in the Cheviot Hills in the South East of Scotland, Sourhope Farm experiences a climate more extreme than that normal to Scotland. Figures from the Farm's own meteorological station are, unfortunately, only available since January 1952. The following results however, abstracted from the British Climatological Atlas, and from Old Graden, near Yetholm, the nearest permanent weather-recording station to Sourhope, give some indication of the general climate of the area.

The prevailing wind is from the South West, but owing to the intervening high ground in the same direction, these winds drop much of their moisture before reaching the area. The mean annual precipitation in Yetholm, seven miles distant, at a height of 500' is 30 inches, whereas, the 1952 rainfall figures for Sourhope Farm, where /

where the station is at 900', indicate a higher figure, probably averaging 35 inches. Rain falls throughout the year but the Spring months show the smallest precipitation, and the largest is from August to Decêmber. In April and May, cold, dry, East winds are frequent. Snow is common from November to April. The Farm records show that in 1952, frost occurred in all months except July and August, though average figures for the area give a frost-free period from mid-May to mid-October.

Temperature readings indicate that January is the coldest month, and July the warmest. The average range is between 32 degrees F to 67 degrees F though temperature-ranges from 10 degrees F to 80 degrees F are common.

THE PLAN AND SCOPE OF THIS SURVEY.

The field-work for this Thesis was carried out on Sourhope Farm between March and November, 1952 and March to June, 1953.

At the outset, a preliminary survey was made, and the main vegetation types to be investigated were selected. Typical sites from each vegetation type were sampled. The Specific Frequency method of vegetation analysis was employed, using a 25 square cm. ~~quadrant~~ quadrat. The soil profile was described, and top-soil and sub-soil samples taken. In the Laboratory on the Farm, these soil samples were estimated for loss of water on air-drying and Loss on Ignition. In the Soils Laboratory of the Edinburth and East of Scotland College of Agriculture, available phosphates and potassium, pH and exchangeable calcium were estimated.

During the Autumn of 1952 some soil samples were taken, across transition zones between the main vegetation types. It was, however, considered that these transitional samples were outwith the scope of this thesis and their results have therefore not been included. The data used have been drawn from the analysis results of approximately 520 topsoil and subsoil samples from 47 vegetation sites. The data for each /

each individual sample and the mean results for each site are found in Appendix II.

Three maps are included. Map 3 is part of Ordinance Survey Sheet No. 51 and shows the position of the farm in relation to the surrounding country and also those sites which are not within the farm boundary. Map 2 is a map of Sourhope Farm on the 3" to 1 mile scale. Map 1 is taken from the Macauly Soil Survey Map reduced to the 3" scale. In Map 3 grid references for site positions are based on the standard O.S. grid. In Map 2 the 1" grid was superimposed by the writer. The references to the sites on the farm are based on this grid.

The thesis is divided into 9 sections:-

Section 1: deals with the literature reviewed. This has been divided into the literature for each vegetation type and principal soil factors. To facilitate reference, the bibliography has been put at the end of each sub-section.

Section 2: This section includes Map 1 - (The Soil Map of Sourhope) and deals with the various soil types present and the sampling method of the soil.

Section 3: This deals with a review of the vegetation types found on Sourhope and the method of vegetation analysis. A short account is given of the probable past forest cover of the area. /

area.

Section 4: In this section, the eight main vegetation types and sub-types are described. Maps 2 and 3 show the positions of the sites, together with 8 sets of profile diagrams. A graph showing the occurrence of the 5 principal vegetation types with reference to soil Loss on Ignition is included.

Section 5: Histograms show diagrammatically the inter-relation of the 5 vegetation types with reference to soil conditions.

Section 6: In this section, the inter-relations of the individual soil factors are discussed. Included are Graphs 2, 3 and 4, correlations between Exchangeable Calcium - pH and Loss on Ignition - pH, and a statistical analysis and comparison of the results for each of the 8 vegetation types, and sub-types with reference to pH and W/H.

Section 7: This deals with the distribution of the 20 principal hill species encountered in this work, with special reference to L.I., W/H ratio and pH.

Section 8: This deals with the general trends and conclusions which can be drawn from the investigation.

Section 9: Summary.

Appendix 1: This is composed of the individual results /

results for the various soil factors for each topsoil and subsoil sample.

Appendix 2: This is composed of the mean results for each soil factor for each site investigated.

Appendix 3: This is a list of wet and dry pH's for 145 soil samples.

Appendix 4: This is a description of the analytical methods employed.

SECTION 1.

LITERATURE REVIEW

AGROSTIS FESCUE.

LITERATURE REVIEW

This vegetation type is characterised by the presence of Agrostis tenuis or Agrostis canina, the bent grasses, with Festuca ovina or Festuca rubra, sheep's fescue and red fescue. The relative amount of each species present in the sward depends upon prevailing conditions, but together they form the dominant species. Tansley, (17) 1949, reports that the Agrostis-fescue community occurs on well-drained siliceous, sandy soils which are distinctly, though not extremely acid. There is little zonation according to altitude, the community being common up to the arctic-alpine zone. It does, however, form a characteristic zone up to approximately 1000' occupying the ground formerly under Quercus sessiliflora and related woodland. Agrostis-fescue is the most widespread of the "natural" grasslands used for grazing, being found on lowland, sandy heaths and commons, and covering large areas of hillsides where it roughly corresponds to the distribution of former woodland. The community is generally poor in dicot species. A few legumes are represented, the most frequent being Lotus corniculatus, the birds-foot trefoil. Pearsall. (14) 1950, discussing the Agrostis-fescue community found in the uplands, states that the soils are of the brown earth type, base deficient, and more or less acid. The community is situated on the steeper, better drained/

drained slopes, the most typical associated species being Potentilla erecta, Galium saxatile, Anthoxanthum odoratum and Cynosurus cristatus. Where the lime content of the soil is higher, Viola lutea and Trifolium repens occur, and the presence of raw humus is indicated by Sieglingia decumbens, Deschampsia flexuosa and Vaccinium myrtillus. Where the soil depth is over 12 inches, bracken (Pteris aquilina) may be common. The soil is of a uniform and open texture, being formed from easily weathered rocks such as basalt and mica-schist. More restricted Agrostis-fescue communities are found on hillsides where the base status of the soil has been raised by percolating spring water. This type is found at its maximum in alluvial pastures, the common plant associates being Deschampsia caespitosa and Holcus lanatus. The community embraces a broad series of types extending from the almost pure Festuca ovina pastures of the limestones and basalts to the poor, unpalatable Nardus- Juncus squarrosus vegetation of peaty, base deficient soils. The community is adversely affected by heavy sheep-grazing, the first indications being an increase in bent followed by Nardus stricta and Juncus squarrosus. In extreme cases, these last two species may eventually become dominant. The Agrostis-fescue pasture, being relatively high in lime, phosphates and protein, is an important source of nutrients for animals. Farrow (3) 1915, and (4) 1916, states

states that on Breckland the Agrostis - fescue community is found on the drier areas and that, as a result of rabbit grazing, Calluna heath is being converted into an Agrostis-fescue type. A similar effect caused by burning Calluna has been noticed by Asprey (1) 1947. on Canina. Leach (13). 1936, comments that in the distribution of vegetation types in the Longmynd district, Agrostis - fescue is found associated with rabbit burrows. Fenton (7), 1937, observes that heavy sheep grazing of the Agrostis - fescue type allows the invasion and the final domination of the pasture by Nardus stricta. On rocks of the more basic type, Fraser (8) 1933, states that, due to grazing pressure, forest regeneration is prevented, and land formerly under sessile oak is now Agrostis-fescue. On less massive rocks and on till, Festuca ovina, Deschampsia flexuosa and Anthoxanthum odoratum are more abundant, and Agrostis and Holcus lanatus are less frequent. Deschampsia caespitosa is indicative of flush soils and does not occur on peat. Fenton (6) 1933, notes on the Pentland hills that the Agrostis - fescue vegetation is mainly confined to flushes and shows how flush conditions or manuring favours the increase of these species. On the coal measures fells in the Durham area, Jeffreys (11) 1916 and (12) 1917 states that Agrostis - fescue is common on a dry sandy soil with a thin surface humus layer./

layer. Like Nardus, this type will not tolerate seasonal flooding. Watt (18) 1936., and (19) 1938., finds in Breckland that some ~~species~~ facies of the Agrostis-fescue community ~~is~~ are found on almost any soil type. It is a frequent coloniser of sand "blow outs", bared by wind, and commonly dominates "frost holes" where bracken, Pteris aquilina, is inhibited. He suggests that this type may form the starting point for a sere, eventually dominated by either Carex arenaria, Calluna vulgaris or Pteris aquilina. The dominance of one or the other, however seems to be only temporary, there being a cyclic change in dominants, but Agrostis - fescue is the permanent, fundamental community.

SOIL CONDITIONS.

Soil Analysis results in the literature are few for this community. Heddle and Ogg (9) 1933 and (10) 1936 give the following description of two areas investigated in the Pentland Hills.

Moist flush pasture:-

Vegetation:- Agrostis - fescue and Holcus lanatus, with Poa trivialis and Trifolium repens (Trifolium may become very prominent where flushing is intense). The topsoil is a well drained, medium loam resting on a subsoil of loam or clay-loam. The soil is slightly acid, Potash is moderately high and phosphates very low. This type is found on the lower hill slopes, the soil having been derived from basic rock, and moisture is moderate at all/

all times of the year.

Wet-flush pasture:-

Vegetation:- Agrostis sps. and Holcus lanatus most abundant with Festuca ovina and rubra, Anthoxanthum odoratum, Deschampsia caespitosa, Nardus stricta and Trifolium repens. The soil has a greyish tint and, though in parts gravelly, has a fair amount of clay. There is no tendency to peat formation. The soil is derived from basic andesites and overlies boulder clay. The soil is wet at the surface and the water is moving. The soil analysis is similar to that found under the moist - flush pasture as described above. Artificial flushing of an Agrostis tenuis - Festuca ovina community with abundant Galium saxatile, led to an increase in Agrostis tenuis and Festuca rubra, and a reduction in Festuca ovina and Galium saxatile. Other species normally increased by flushing are Holcus lanatus, Trifolium repens and Poa trivialis, whereas Deschampsia flexuosa, Vaccinum Myrtillus and Nardus stricta show a corresponding decrease.

Farrow (6) 1917. shows that increasing the water supply to an Agrostis - fescue type allowed the Agrostis species to increase at the expense of Festuca ovina. Tansley (17) 1949 quotes the following p.H. figures for the Agrostis - fescue community: Malverns - 5.0, Clee Hills - 4.9, Wales - 4.2, and the Cahn Hill 4.3 - 4.7. The/

The general range is from p.H 4 - 5. Cooper (2). 1932. gives the range of Agrostis tenius and canina as 4.5 - 6.0, and Small (15) 1940 Agrostis tenuis p.H. 3.5 - 5.9, Festuca ovina and rubra 4.0 - 7.9.

Smith and Crampton (16) 1914 in their paper on the "Grasslands in Britain", include Agrostis and Festuca ovina as part of the turf forming types. The former species is considered to be "migratory" and the latter "stable".

AGROSTIS FESCUE.

LITERATURE.

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CALLUNA VULGARIS.

LITERATURE REVIEW

Distribution and Position:

Calluna moorland is found in North-East Scotland, where the rainfall is lower and less evenly distributed, where the number of days of bright sunshine is greater and the relative humidity is lower than in the climax Scirpus moor along the West coast. (Fraser (15) 1933.) This general trend of the main Calluna moors towards the Eastern half of Britain, is borne out by Elgee, (10) 1914, who shows that from west to east across the British Isles, i.e. along a gradient of decreasing rainfall, the moorland type changes from one of wet, green, Sphagnum bogs in Ireland, through the Pennine Eriophoreta to the thin heathy Calluneta of the Eastern moorlands. Smith, (28) 1903, further states that where the rainfall is approximately 38 inches per year, Calluna is dominant on peat from 1 to 5 feet thick, the wetter parts being colonised by Eriophorum and the drier "edges" by Vaccinium. Adamson, (1) 1918, concludes that the distribution of Calluna is controlled by exposure or water in time of drought, and that the species favours gentle slopes. Metcalfe, (24) 1950, when considering the distribution of mountain Callunetum, also lays emphasis on exposure and wetness, but further includes altitude, slope and snow/

snow coverage as further factors. Evans, (11) 1932, working on Cader Idris, found that heather moor occurs from 1,200 - 1,700 feet, optimum growth taking place between 1,100 - 1,600 feet. The Callunetum favours the more even dip slopes. In the Longmynd, Leach, (22) 1931, fixes the lower limit of true Calluna heath at 1,400 feet on hill slopes. Smith, (29)1911, in a discussion on Scottish Heaths, asserts that "Calluna heath" is mainly encountered in the eastern part of the country, and occurs from sea-level to 2,000 feet. Farrow, (14) 1925, in a paper on the earlier distribution of Calluna Heath in Britain, claims that it is intermediate between grass heath and woodland, depending on biotic pressure. He considers that Calluna must have been more widespread than at the present day, and that most of the heaths had been wooded. In an earlier paper by the same author, (13) 1916, he shows the grazing effect of rabbits as a major factor in the conversion of a Calluna heath to an Agrostis-fescue sward, a change corroborated by the work of Asprey, (3) 1947. A full account of the structure, life-history and distribution of Calluna valgaris is given in a monograph on this species by Beijerinck, (4) 1940.

Calluna - Soil Conditions:

In their paper on the rooting system of heath plants, Heath and Luckwill, (18) 1938, report that/

that Calluna has a shallow root system with considerable lateral spread. The surface layers of the soil are exploited by a mass of fine adventitious roots, the main working depth of the root system being 10 centimetres with a maximum of 20 centimetres. Adamson, (1) 1918, in his report on the South Pennine Calluneta, states that there the peat is sandy and rarely over 1 foot thick. Below the peat is a much stained, sandy, sub-peat layer which is freely penetrated by roots, ~~which~~ penetrating the sub-peat layer at approximately 25 centimetres. Whether these roots play a major role in the supply of nutrients to the plant is not stated. Farrow, (12) 1915, records the main absorbing area of the Calluna rooting system to be from 5 to 15 centimetres, though main roots are found down to 40 centimetres. The soil is podsolised sand showing a B_1 and B_2 horizon, but no A_2. An iron pan is present at depth. Pearsall, (25) 1938, summarises the following conditions for heather moor: the peat is 10 centimetres or over in depth and is oxidising, though nitrates are absent. Bases are markedly deficient, the pH ranging from 3.4 - 3.7. The peat type is constant having two main features:-

(i) It is similar to woodland Deschampsia flexuosa soils and may be the unshaded equivalent, Calluna commonly being found on the site of former forest./

forest.

and (ii) It resembles woodland mors in that there is no scarcity of oxygen.

Woodhead, (51) 1906, discussing the vegetation of the district round Huddersfield, observes that the Calluna zone is on the Millstone Grit. The soil is shallow, sandy and well drained, the peat having a thickness of 6 - 12 inches. Fritsch and Salisbury, (16) 1915, in their observation in the Hindhead area, report that Calluna attains its maximum development on peat from 3 - 5 inches thick. Elgee, (10) 1914, states that Calluna develops best on "fat" moor, i.e. where the peat is over 6 inches in depth. He distinguishes four types of dry and two types of wet, heath Calluneta; also there is the Callunetum found on deep peat ("fat" moor), and two types of ~~mere~~ moor Calluneta on deep peat bogs. Working in the Eden, Tees, and Tyne valleys, Lewis (23) 1904, reports two main types of Callunetum. One is situated on dry slopes where the peat is thin the associated species being Deschampsia flexuosa, Juncus squarrosus, Vaccinium myrtillus and Nardus stricta. The second is where the peat is deep and wetter. Moor pan is commonly present, the main associated species being Erica tetralix and Eriophorum vaginatum. Armstrong et al., (2) 1929, report six main types of Calluneta from the Mourne Mountains. Hagging of the peat is also noted in this district, the exposed surfaces being /

being colonised by Festuca ovina. The same writers state that the pH's of all the types are between 4 and 5. pH figures for this community show much variation. As already reported, Pearsall, (25) 1938, gives a range of 3.4 - 3.7, Domin, (9) 1926, 3.8 - 5.5 (seven samples) with a mean of 4.83, Kertland, (20) 1928, 4.5 - 6.0, Conway, (5) 1949, a pH of 3.5, De Silva, (8) 1934, a range of 4.7 - 5.2 with a mean of 4.9, Fraser, (15) 1933, 3.0 - 4.2, the mean being 3.3. Klapp, (21) 1951, finds no difference between the acidity of Nardus and Calluna land, the range for Nardus being 3.4 - 5.8 with a mean of 4.0 - 4.3. Leach, (22) 1931, shows that Calluna, though present on grits where the pH is 4.2, is absent on contiguous purple slates where the pH is 5.9. Rayner (26) 1913, observes that the distribution of Calluna on the Downs is associated with patches of clay with flints, and she further shows, (27) 1921, that Calluna will not grow in calcareous soils. Despite the evident poverty and acidity of the soil in which it grows, Calluna which has a low lime requirement has a high "feeding power for lime", (Rayner (27) 1921. Thomas, (30) 1934, has also maintained that the mineral content of the Calluna plant with respect to calcium and phosphates is relatively high.

Calluna - Soil Water Relations:

In his paper on a Welsh Upland Bog, Davies (7) 1944, throws some light on the relationship/

relationship of Calluna to soil wetness. He notes that drying of the soil has allowed Calluna to colonise a strip of ground originally Scirpus caespitosa. Where further drying has taken place, Calluna is replaced by Vaccinium myrtillus. Evans (11) 1932 states that drainage determines peat communities in Cader Idris, and that Calluna heath is to be found on the better drained lower slopes. Farrow (12) 1915, notes on Breckland that Erica tetralix colonises the wet, deep peat and Calluna the drier areas. Near Sheffield, Conway (5) 1949, reports Calluna on the drier areas round the bog flush, and Harley and Yemm (17) 1942, state that, owing to a rise in the ground water level, a Calluna-Eriophorum vaginatum association grades into a Sphagnum - Eriophorum angustifolium type. Calluna is found on the areas made drier by increased peat growth and the lowering of lateral drainage. Jeffreys (19) 1917, claims that Calluna requires less water than Nardus, though the water content of the soil below Calluna is higher. He shows that by reducing the water supply to a Nardetum, Calluna is favoured and shortly becomes dominant. Crump (6) 1921, in his analyses carried out in connection with his coefficient of Humidity, quotes for the "humidity" of Heather moor: Thin surface peat over 25% Organic Matter, (fourteen samples) - Mean W/H 2.31. This figure, corrected to allow comparison with those obtained by the writer, is 2.49. Subsoil figures for fourteen samples are - Crump, 3.17 (corrected - 3.24).

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NARDUS STRICTA

LITERATURE REVIEW

With the exception of Calluna vulgaris, few hill species have received more attention in the literature than the moor-mat grass, Nardus stricta. This is partly because large areas of hill country are colonised by this species, and partly because it has become an indicator species of poor, worn out land over-grazed by sheep. As it is a plant which will tolerate a wide range of habitat factors, few references are made to its position as a natural hill plant community, and in many cases it appears to be assumed that owing to the action of some external factor, usually biotic Nardus has ousted some former vegetation. In many cases this is undoubtedly true. Fenton, (8) 1939, (6) 1936, (7) 1937, and (5) 1933, in a series of papers makes reference to Nardus. He associates Nardus with poor, worn out soil and as a selective biotic climax between heath and grassland, favoured in its spread by the grazing of sheep. Sheep grazing, he further contends, is detrimental to Calluna vulgaris. That the grass is nutritionally of little value has been shown by Thomas and Trinder, (20) 1947. Calcium and phosphorus are both very low, even in relation to other hill species, and/

and the high silica content of the leaves makes them very stiff and unpalatable. The same authors comment upon the occurrence of Nardus with hard, dry moors and when associated with Calluna with a thin peat covering. Smith, (17) 1918, finds that Nardus commonly forms a zone below the peat hags on the Lammermuir Hills, colonising the redistributed peat washed down from above. Thomas and Dougall, (21) 1948, suggest that redistribution changes the colloidal character of the peat and consequently its water content, the new habitat so formed being suitable for the growth of Nardus. Tansley, (19) 1949, summarises the Nardus habitat as being found on siliceous soils of medium dampness, where the conditions favour the accumulation of acid, peaty humus, or on redistributed peat. The sod is 8 - 12 inches thick on an impervious subsoil. The community is intermediate between a Fescue - Agrostis and a drier peat type. It is floristically poor, Juncus squarrosus and Vaccinium myrtillus being common associates on the drier type and Molinia caerulea on the wetter. Pearsall, (16) 1950, further states that Nardus is most frequent between 1,000 and 2,000 feet, extending on some of the more gentle dip slopes up to 3,000 feet. Its distribution corresponds with the region of highest rainfall and most severe leaching of the soil. The soil is acid, peaty/

peaty and base deficient usually oxidising in summer and so resembling heather moor, though damper. Another common site of Nardus is on well washed, poor, sandy alluvium near hill streams. Nardus with Juncus squarrosus may be taken as a sign of disturbed peat, some contact with the mineral soil appearing to be necessary. Its intolerance of shading excludes it from woodland and from competing favourably with the larger grasses and bracken. It is frequently to be found on the sites of former woodland where leaching and grazing have been active. Adamson, (1) 1918, states that Nardus becomes truly dominant on gentle slopes where peat can accumulate and the drainage is poor. The peat is about 6 inches deep, and the sub-peat layer is less distinct than that found under heather. Where the slopes become steeper, or the peat drier, Deschampsia flexuosa increases. He therefore associates Nardus with a peaty soil where the surface drainage is imperfect. Evans, (4) 1932, states that Nardus occurs on the better drained upper slopes of Cader Idris, the associated species being Galium saxatile, Erica tetralix and Juncus squarrosus. Between 1,800 and 2,000 feet the vegetation grades into the Arctic - Alpine type. In this paper an/

an interesting zonation of vegetation round moorland pools is reported. This ranges from the wettest - Eriophorum angustifolium - Sphagnum type - through Eriophorum vaginatum, Juncus squarrosus and Erica tetralix, to the drier Calluna, and finally to Nardetum. Metcalfe, (18) 1950, however, discussing the mountain Callunetum, observes that Nardus dominates in depressions where the snow lies longest. The peat depth is considerable, and is very wet due to seepage.

Soil analysis figures for Nardeta are few. Heddle and Ogg, (10) 1933 and (11) 1936, quote the following results in papers on the improvement and flushing of Scottish hill pastures. On a Nardus - Vaccinium type on glacial drift with a peat layer 1 - 3 inches thick, loss ~~at~~ on ignition was 30 - 50 per cent, and pH 4.25. Available potash was high and available phosphates very low. Sub-surface samples showed lower loss ~~at~~ on ignition potash and phosphate figures, though the soil was slightly less acid. A similar trend was shown by results from a Nardus - Agrostis - Fescue - Holcus type where the slope was more gentle and the drainage more impeded.

TABLE /

TABLE

Type	pH	Available K_2O	Available P_2O_5	Ex.Ca.%	L.I.%
Nardus - Vaccinium	4.25	15	4	0.04	21.0
Nardus - Agrostis - Fescue - Galium	4.4	12	4	0.04	13.0
		Mgms. per 100 gms.	mgms. per 100 gms.	As % CaO	

Klapp, (14) 1951, investigating Nardus grasslands in upland regions in Germany, gives the following results, being the mean of ninety estimations:-

pH	Mean	4.0 - 4.3 (Range 3.4 - 5.8)
Avail. P_2O_5	Mean	1.45 mgms.
Avail. K_2O	Mean	12.72 mgms.

The areas were all over 500 metres and the rainfall was approximately 700 millimetres per annum. The soils were cohesive with numerous gley horizons. Moor pan was not present. He states that the inferior pastures of these regions are due to soil conditions and uncontrolled over-grazing. Domin, (3) 1926, gives a range of pH from 4.0 - 5.2, with a mean of 4.55, for Nardus. Four samples were taken. Jeffreys, (12) 1916, states that Nardus will tolerate a high water content in the soil, but not flooding,. The same author, (13) 1917, observes that artificial lessening of the water supply to a Nardetum causes reduction of tissue/

tissue and an eventual replacement of Nardus by Deschampsia flexuosa and Festuca ovina. De Coulon, (2) 1923, discussing the physiology of Nardus, reports the interesting fact that, despite the high acidity of the medium, Nardus utilises and thrives best on a supply of nitrogen in the form of nitrates, in preference to ammonia nitrogen. Potassium nitrate, however, must be the source of the nitrates, calcium nitrate, even at high acidities, having a toxic influence.

Heath and Luckwill, (9) 1938, describe the rooting system of Nardus as being typical of heath monocots. It is deep with little lateral spread with a normal working depth of 2 - 15 centimetres and a maximum of 30 centimetres. The top 8 centimetres are occupied by closely growing rhizomes which branch to give tussocks. Smith and Crampton, (18) 1914, in their paper on "Grassland in Britain", class Nardus as a migratory tussock-forming species. Soil and humus are accumulated between the leaf bases, and the plant is a peat former.

NARDUS STRICTA

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MOLINIA CAERULEA - LITERATURE.

Molinia Caerulea, the flying bent or purple moor grass, colonises large areas of the Southern Uplands. Fraser (3) 1933, writes that this species is typical of the south Scottish moorlands. It may represent a stage in the succession from mineral soil to scirpus moor, the latter being found at higher elevations where rain-fall is greater and temperatures lower. Molinia moor, however, appears to be a stable vegetation type where summer temperatures are such as to allow some drying of the soil, thus permitting upward movement of water containing mineral matter. The community is commonly pure, having few associated species, forming large tussocks at maximum development. With a lessening of surface drainage, Eriophorum vaginatum and Erica tetralix increase. Molinia usually with Eriophorum vaginatum is typical of wet hillside flushes where the mineral content of the percolating waters is intermediate between that of the relatively rich Rush flush and the very poor Eriophorum vaginatum types. Molina grows in a characteristic form of organic matter, decay of the peat having reached a stage at which a mould or type of true humus has been reached. This is termed by Fraser, "amorphous, granular peat". The pH range of the Southern Upland Molinietum is given as 2.6 - 5.8 with a mean of 4.3/

4.3. Jeffreys (7) 1916, correlates the occurrence of Molinia with the presence of water of a high organic matter content, and as growing on an organic soil of a stage between humus and peat. The same author (8) 1917, reports that Molinia prefers a soil with a higher organic matter content than Nardus stricta, and can tolerate periods of winter flooding. Molinia is inhibited by reducing its water supply, Calluna vulgaris eventually superseding it. The same drier conditions favoured an increase in Potentilla erecta. Jeffries (9), 1915, discussing the ecology of Molinia, shows that this community is present where the soil water is moving, forming a zone between Nardus stricta and Eriophorum vaginatum. This is not due to the differing water contents, of the soil, but to the fact that Molinia demands moving water of a relatively high base status. With regard to soil water content, Jeffries places Molinia between the drier Callunetum and the wetter Eriophoretum. Pearsall (11) 1938, states that, as a result of washing, Molinia flushes contain nitrates. The species may occur on oxidising soils with a pH below 3.9, or on reducing soils where the pH is over 4.4., as exemplified by the Connemara Molinieta. It would appear that the plant can tolerate higher acidity when oxygen is present in the soil water. The same author (12) 1950 in his book "Mountains and Moorlands" gives this summary /

summary of the Molinia habitat: The plant colonises peat which is damp, if not wet, for most of the year. On reducing bog soils, the Molinia is small and untufted, the tussock form being found on aerated soils. The species is an active peat-former, often marking the transition from fen to bog, or damp woodland to bog. It is also common along the lower margin of peat mosses where it is flushed by peaty water but only where summer drainage is good. Though Molinia has a low lime-requirement, the peat has a higher ash content than is required by most moorland plants. It can also tolerate, or may require a high iron supply, as its presence on iron flushes confirms. It is thus typical of soils which are peaty, base deficient, short of lime and damp, where iron is being mobilised. Gorham (5) 1953, in a discussion on the base status of raised and blanket bogs, shows that in Irish blanket bogs where the main vegetation is of a Molinia - Schoenus type, the pH is 5.2 In comparable British raised bogs the vegetation is Calluna - Sphagnum and the pH is 3.3. The water content of both is similar and it appears that the difference in vegetation is related to the difference in base saturation of the two types. In a similar vein, Duff (2) 1929, shows that Molinia forms a zone on the unflooded ground round the basic water of Lough Neagh. It grades, farther from the loch, into Callunetum./

Callunetum. Godwin and Conway (4) 1939, report in the study of a raised bog, that, during a dry period in the year, the water level was highest under Sphagnum and lowest under Molinia. Summerhayes and Williams (14) 1926, in a paper on the recolonisation of felled woodland in Surrey, noted that once the trees are removed Molinia spreads rapidly especially where the soil is damp. Molinia is associated with Calluna in the drier parts and with Erica tetralix in the wetter. With increasing water, Molinia grades into a Juncus community and the wettest areas support a Sphagnum vegetation. McVean (10) 1952, states that Molinia requires horizontal and vertical water movement. The amount of oxygen in the soil water seems to have little or no importance. Where stagnation or mineral impoverishment occurs, degeneration of the Molinia takes place with the invasion of the community by the moss, Polytrichum commune. Thomas and Dougall (16) 1939, state that Molinia is found in varying soils and topography. The plant can stand a high degree of acidity and wet, but not waterlogged conditions. It is common on well drained flushes and may be exclusive, or with associated Juncus squarrosus and Nardus stricta. Molinia is intermediate in wetness between the drier Nardus and the wetter Scirpus communities. Thomas and Trinder (15) 1947, show that the chemical composition of Molinia compares favourably/

favourably with lowland grasses in all but calcium content, in which respect it is much lower. Crump (1) 1911, basing his result on 9 Molinia samples, concludes that Molinia peat, though as pure as that under Calluna, is distinctly drier with a W/H under 2.00. Heath and Luckwill (6) 1938, report the rooting system to be the same as that found in other heath Monocots, while Smith and Crampton (13) 1914, class Molinia in the Stooled-Meadow category of exaggerated tussock type. It accumulates silt and raises itself above the normal flood level.

MOLINIA - LITERATURE.

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LITERATURE REVIEW.

Deschampsia flexuosa, the wavy hair grass, is included by Tansley, (19) 1949, as one of the Acidic Grassland species. It is found on the more acid, sandy siliceous soils, with a tendency to peat formation. The plant is commonly present in Callunetum and associated with Nardus, rooting in the surface mat of raw humus. In Breckland, Deschampsia flexuosa is dominant on the more acid heaths where thin peat is formed. Pearsall, (15) 1950, states that Deschampsia flexuosa is characteristic of the steep slopes of the Pennines, where the underlying rocks are poor in bases and the rainfall is relatively low. The species is an indicator of acid mor humus, commonly replacing Juncus squarrosus on the drier types of Nardus. It is common to exclusive in the ground flora of the dry, acid, leached, sessile oakwoods of the South Pennines. Above the woods, this species is replaced by Calluna vulgaris--possibly as a result of the increased light intensity--though Deschampsia flexuosa remains as a subsidiary species in the Callunetum. The soils are all highly leached and frequently grade into types dominated by Nardus or Fescue/ Agrostis. Adamson, (1) 1918, records that Deschampsia

Deschampsia flexuosa and Nardus stricta occur on steeper slopes or drier peat. Where the peat is thin and the slopes are liable to drought, Deschampsia flexuosa becomes truly dominant. Jeffreys, (7) 1916, states that it commonly forms a zone between ~~between~~ Nardus stricta and Pteris aquilina, when the Pteris is limited by soil water content. The same author further shows, (8) 1917, that where Nardus stricta is reduced, owing to lack of water, Deschampsia flexuosa and Festuca ovina increase and eventually occupy the ground. Jowett and Scurfield, (9) 1949, discussing the distribution of Deschampsia, state that it is found on exposed, steep slopes with highly organic, sandy soils, as those found associated with pine (Pinus sylvestris), birch (Betula alba) and sessile oak (Quercus sessiliflora) woodland. It is also common on sandy heaths in competition with Pteris aquilina, Vaccinium Myrtillus and Calluna vulgaris. On Lochnagar in the Cairngorms, it has been recorded up to 3,800 feet. Soil and light conditions appear to be optimum where it forms the ground flora of pinewood, and it is suggested that the distribution of this species may coincide with that of Pinus sylvestris. Smith, (18) 1918, in his paper on Nardus stricta, states that on the steep, dry, valley slopes in South-East Scotland, a Deschampsia-Agrostis-Galium saxatile community is found extensively. In the upper part of the zone/

zone, towards the peat margin, Nardus stricta becomes abundant to sub-dominant.

Soil Conditions:

Pearsall, (15) 1950, and (14), 1938, states that Deschampsia flexuosa colonises soils which are strongly leached. The organic matter is of the acid mor type. The soil is free of earthworms and, though nitrates are absent, strongly oxidising. This condition is probably due to acidity, the pH being below 3.8. The results of nine samples showed a pH range of 3.3 - 3.8. Jowett and Scurfield, (10) 1952, conclude that this species occurs on soils having a high organic matter content and a low pH. The pH was below 3.8. It is one of the first colonisers of raw woodland humus, in which it may bring about a series of changes converting the raw mor to a form of mull. This change in humus character permits the invasion of other species, one of the most common being Holcus mollis. It is also shown that a high organic matter content in the soil implies a high moisture content, and that a high pH implies low organic matter and low moisture. The same authors, (7) 1952, in a statistical investigation into the distribution of Deschampsia flexuosa and/ Holcus mollis proved that Deschampsia was more successful on soils of a lower pH than Holcus. They further conclude that owing to the low pH and low exchangeable base content of the soil, the base re-

requirements of Deschampsia are low and that it utilises nitrogen in the ammonia form. Ovington, (13) 1953, makes a further comment on the ameliorating effect of Deschampsia flexuosa in converting mor to a more mull type of humus. Scurfield, (16) 1953, in a recent paper on the ecology of some South Pennine woodlands distinguishes two main types. One occurs on Millstone grit, the profiles all showing signs of active podsolisation, and the ground flora is of the Deschampsia flexuosa - Vaccinium type. Twelve estimations of pH under Deschampsia dominant areas give a mean figure of 3.8. In the second woodland type, on fine grained sandstones and shales of the Coal Measures Series, podsolisation is again found under Deschampsia flexuosa, but not so strongly as in the previous case, the ground flora resolving itself into a Pteris - Holcus - Scilla - Deschampsia type. Seven estimates of pH under Deschampsia gave a mean figure of 4.2. In both woodland types the percentage loss on ignition is very similar (28%), though the less acid Deschampsia type is much drier. Crump, (3) 1913, states that Deschampsia is found on fine, sandy humus, and that the loss on ignition figures at 2 - 4 inches is 44%, and the W/H ratio is 0.75. Olsen, (12) 1938, obtained the following results when growing Deschampsia in nutrient solutions and soils of varying pH. It flourished in cultures with a /

a pH of 3.0, but over pH of 7.o, little growth was made and the plant eventually died. It is suggested that manganese, only available in acid soils, may be necessary for the growth of this species. Growth is optimum in a raw humus soil with a pH of 3.8 - 4.0, though high calcium in the soil is not injurious to the plant. The same author, (11) 1935, gives the pH range of Deschampsia as 3.8 - 4.5. Domin (4) 1926, gives the pH range as 4.4 - 5.6 with a mean of 4.88, (six estimations). Small (17) 1940 quotes the pH range as 3.5 - 6.3 with an optimum in the soil of 5.5, and in cultures of less than pH 4.00. Atkins and Fenton (2) 1939, show a range for Deschampsia of 3.8 - 5.5 with a mean of 4.0. Heddle and Ogg, (6) 1936, in a mixed vegetation type containing Vaccinium and Deschampsia, quote the following figures:- pH 4.4; Loss on Ignition 20%; Available potash. 19 milligrammes per 100 grammes air dry soil; Available phosphates, 8 milligrammes per 100 grammes. Heath and Luckwill, (5) 1938, assert that Deschampsia flexuosa has a rooting system similar to that of normal heath monocots.

DESCHAMPSIA FLEXUOSA

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HYDROGEN ION CONCENTRATION

LITERATURE.

Of all the soil factors said to play a part in the distribution of plants, none has received more attention than hydrogen ion Concentration or pH of the soil. The literature available on this subject is extensive, and will be dealt with under two headings: (1) The relationship between pH and other soil factors (including the effect of pH on other soil factors) and (2) The effect of pH on the growth and distribution of the plant.

(1) Truog (46) 1918, discusses the effect of pH as (a) the indirect effect and (b) the direct effect of acidity.

(a) includes the deterioration in physical condition of the soil, the preservation of soil organic matter and non-precipitation by calcium of toxic substances. Phosphates are fixed in the highly insoluble form of aluminium and iron phosphates, and phosphorus also reacts with the acidic organic matter forming less available phosphates. Ca, Mg, Na and K become less available as a source of plant nutrients whereas Fe, Al, Mn., Cu and Zn--many of which are toxic to plants in concentration --become more available.

(b) The direct effect of a low pH is associated with small amounts of available calcium. The Nitrogen fixing microflora of the soil is inhibited by its reduced ability to migrate to new hosts, though fixation of Nitrogen in the nodule will/

will continue at pH's lower than those which will curtail migration. Pearsall (36) 1952, indicates that there are significant limits of pH in the soil and affirms that obvious boundaries exist between pH 3.8 to 4.0 and 4.8 to 5.0. pH is also related to base exchange and rainfall. An increase in soil organic matter corresponds to an increase in soil acidity, a view shared by Jowett and Scurfield (21) 1949, and the formation of a mull or mor type of humus is correlated with soil pH. Below pH 5, humus forms on the surface layer of the soil, whereas above this figure, it is distributed more evenly through the soil profile. The ratio of Carbon to Nitrogen, C/N, increases with a lowering of pH, and is over 20 at a pH of less than 3.8. In peats, Pearsall finds no connection between pH and "wetness", but rather between pH and the oxidising or reducing nature of the peat. This last factor was more fully investigated by Pearsall(34) 1938. Briefly, in an oxidising-reducing system or "Redox" system, the ratio of oxidised to reduced products can best be expressed in terms of potential and pH. The practical application of this principle to peats showed that an increase in the oxidising powers of the peat, lowered the pH while a decrease raised it. Thus pH may be related to the degree of oxidation where the organic matter percentage is the same. Pearsall (33) 1926, also suggested that soil sourness could be attributed not only to a/

a deficiency of calcium, but also - as a result of more speedy leaching of calcium - to a distortion in the ratio of bases in the soil. He thus concluded that in sour soils, the ratio of $\frac{K+Na}{Ca}$ would be much higher than in normal ~~s~~oils near neutrality. Salisbury (42) 1925, working on soils with a limestone subsoil, found that acid soils showed a concentration of potassium and magnesium in the upper layers as a result of the more speedy leaching of calcium. He asserted that calcifuge plants had a high uptake of potassium, and suggested that acidity effects might be linked with high amounts of potassium. The latter assertion, however, was not proved. Further, and contrary to the findings of Pearsall (33) 1926, experiments showed for species, a very wide range of the basic ratio, though Salisbury had shown that the soil reaction did govern the availability of the main ions.

Reports of many experiments are available where plants were grown in nutrient solutions of known pH. Arnon (2) 1942, in experiments to show the effect of pH of nutrient absorbtions by plants, found that, at a pH of 3, growth failed in tomato, lettuce and Bermuda grass, calcium absorption ceased and phosphate intake was severely curtailed. From pH5, the reduction in calcium absorption was evident, though, with regard to the intake of K, Mg and nitrates between pH 4 and 9, no external reaction in the plant was noted. At a pH of 9, phosphate absorption was again curtailed./

curtailed. Arrhenius (3) 1926, carried out water culture experiments to work out the optimum pH range for agricultural crop plants which he correlated with field samples. Similar experiments were made by Powers (37) 1927, though he reported that in his solutions over 2 p.p.m. of aluminium were toxic to the plants.

That the solubility of aluminium is related to pH has been fairly well established, but on its concentration in the soil and its toxicity to vegetation, accounts are contradictory. Robinson (38) 1951, reports that below pH 5 aluminium is active and is a specific root poison, a view held by numerous workers. Russell (40) 1950, states that when in excess, aluminium enters the roots in acid soils and affects the power of translocating phosphates. Line (27) 1926, however, in a report on aluminium in acid soils, states that over pH 5, it is unlikely that aluminium can exist in a soluble state. Hardy (16) 1926, gives a full account of the relevant literature on the role of aluminium in the soil. Olsen (30) 1938, suggests that aluminium may resemble manganese in its degree of toxicity in the soil; each being apparently toxic in high concentrations, the uptake of both is inversely related to pH. Olsen (31) 1938, relates pH to the intake of iron salts by the plants. He stresses the reaction between iron and phosphorus as the cause of chlorosis, and shows that various plants have a different/

different demand for iron which in the ferrous form, is most available to them.

Working on podsolic soils, Hendrickson (18) 1924, found that, though the pH of the topsoils was the same, the pH of the lower layers depended on the soil structure, texture, aeration, and internal drainage. Lack of aeration and impeded drainage increased the acidity.

For purposes of routine estimation, the effect on pH of drying and rewetting natural soils has been noted by many. Baver (6) 1927, for instance, found drying had little effect on the pH of an acid soil but lowered the pH of an alkaline soil. Conversely Rost and Fieger (41) 1923, showed that drying raised soil acidity which remained after rewetting. Similarly, in soils stored moist for 3 months, acidity increased. Romell (39) 1932, found that on storing, mor became more acid while mull became less acid. Seasonal variations in acidity showing an increase in summer and a decrease in winter were reported by Conway (7) 1949 and Baver (6) 1927. Kelley (23) 1923, discovered that in time of drought, acidity increased. Romell (39) 1932, and Kelley (23) 1923, both indicated that acidity was related to soil micro-flora, the amount of fungi increasing with the acidity; further, that acid mor humus was decomposed by fungi and mull humus by bacteria.

Finally, Cooper (9) 1932, related pH to the percentage base saturation of the soil exchange/

exchange complex. He considered that this, as a factor affecting plant distribution, was more important than hydrogen ion concentration.

2. The effect of pH on the growth and distribution of plants. Shawarbi (44) 1952, summarising the effects on the plant, includes the following: (a) the interaction of pH differences on cation permeability through plant membranes (b) the entry of acid into the plant roots from surrounding solutions (c) the inhibition of enzyme processes (d) the disturbance in the nitrate-ammonia balance and (e) the disturbance of the balance of minerals passing through the root membrane. Truog (46) 1918, stated that the pH of the soil solution had little direct effect on the root tissue, as the pH of the cell sap is between 4 and 6 and is highly buffered. Gustafson (14) 1926, working on pH zones on a lake margin, also claimed that pH affects cell wall permeability.

By far, the bulk of ecological work on hydrogen ion concentration has been done on pH optima and ranges for plant species. Foremost, perhaps, among these investigators, are Small (45) 1940. Wherry (50), 1920 and (49) 1920, Gustafson (14) 1926, Cooper (8) 1932, Atkins (4) 1920, Atkins and Fenton (5) 1930, Pearsall (35) 1938, Olsen (32) 1938, Domin (10) 1926, while Ikenberry (20) 1936, and Montgomery (28) 1931, have compiled lists relating mosses to the pH of their substratum. /

substratum. In some cases the usefulness of these findings is reduced as the number of samples investigated to provide mean and range figures, is not stated or the results are based on few and insufficient analyses. Emmett and Ashby (11) 1934, carried out an experiment in the soil reaction associated with the occurrence of Vaccinium myrtillus and Pteridium aquilinum. They collected a large number of random soil samples and noted each sample where either species occurred. They then compared the mean for each species with the general mean for all the random samples, and concluded that, between 4.7 and 6.2, pH plays no part in the distribution of Vaccinium myrtillus and Pteridium aquilinum. Similarly, Geisler (12) 1926, found no direct correlation between species distribution and soil reaction though he asserted that the early stages of a plant's life showed a narrower range of pH tolerance than the later stages.

Kurz (26) 1923, concluded that plants have a broad tolerance of acidity, but noted that acid clays and silts had different plant associations from acid sands, and that acid or alkaline sands contained species not found on clay or silt.

Salisbury (42) 1925, sampled four species, Vaccinium myrtillus, Pteris aquilina, Scilla nutans and Psamma arenaria, and plotted in a graph, their frequency against pH. The species showed modes of occurrence in relation to pH, and in the case of /

of Vaccinium Myrtillis and Scilla nutans, a bimodal form on the acid side was indicated. In the case of Ficaria verna and of Mercurialis perennis, the curve was markedly bimodal--a mode occurring on both sides of neutrality. The results thus show the range of pH for each species and the optimum pH levels for growth, though the work of Emmett and Ashby (11), 1934, as previously reported, cast some doubt on the validity of these findings. Salisbury (42), in water culture experiments, found further that plants could alter the pH of their growth medium nearer to their optimum level, though, owing to its high buffering capacity, it is doubtful whether this alteration would take place in the soil to any marked degree.

Wherry (51), 1927, correlated the reaction preference of a species with its geographic range. He further pointed out that closely related plants of southern distribution favoured more acid soils than those of a northern distribution. This, he suggested might be connected with the ice covering and boulder clay additions to northern soils during the Ice Age, making these soils less highly leached than those of their southern, unglaciated counterparts.

In connection with the relation of hydrogen ion concentration of the soil to the various upland and moorland plant communities, results are given by Tansley (47), 1950, Olsen (29) 1925, Pearsall (35), 1938, and (36) 1952, Conway (7) 1949, Hora (19) 1947, Jowett and Scurfield (21) 1949 and (22)

(21) 1949, and (22), 1952, Klapp (25), 1950, Armstrong et al (1) 1929, Cooper (8) 1932, De Coulon (9) 1922, Gorham (13), 1953, Haines (15) 1928, Heath and Luckwill (17) 1938, Kertland (24) 1928, Scurfield (43) 1953, Watt (48), 1940, and some others Their results, in relation to those of the writer, will be discussed at a later stage.

Taken generally, the information available shows that different species of plants grow in soils of a specific pH range, though the extent of this range varies greatly between species, and can seldom be reduced to fine limits. Hydrogen ion concentration itself, is seldom if ever, the controlling factor in plant distribution, and the effect of acidity on the other soil constituents and factors is considered a more likely cause. It may be accepted, therefore, that in any ecological investigation, pH estimations, as a reflection of prevailing soil conditions, are significant and of the highest ~~value~~ value.

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SOIL WATER.

LITERATURE REVIEW

As the medium by which the plant obtains the bulk of its nutrients, water, one of the major factors governing the distribution of plants, has received much attention from ecologists. Kramer (24) 1949, in his book on plant and soil water relationships, fully discussed the role of water in the soil, with special reference to its availability, measurement and utilisation by the plant. In the investigation carried out by the writer, water is treated as an ecological factor in plant distribution. In spite, however, of the many references in literature to this aspect of ecology, little conclusive, quantitative evidence is offered to support the view that water is such a factor. The main reason for this is that, whereas accepted methods are employed for examining soil properties such as pH and exchangeable Calcium, no reliable routine method so far, seems to have been established which will allow comparison of soil 'wetness' as a characteristic of the various groups of plants. A further complication is that methods of soil water estimation, (Kramer (24) 1949,) even when giving similar absolute results, do not necessarily imply that equal amounts of water are available to the vegetation they support. Hansen (14) 1926, and Keen (22) 1920, in a review of the relevant literature to that date, stressed the importance of the colloidal constituents of the soil

soil as that fraction most intimately connected with its water-holding capacity. In more recent years, however, Baver (1) 1948, laid additional emphasis on the size and distribution of pore space in relation to water-holding capacity and soil drainage.

As the soils under review by the writer were of an upland type where organic matter was generally high and clay low, a method of water estimation based on that of Crump, (5) 1911, and (6) 1913, was adopted. This is fully discussed in the Appendix 4. Crump (5) 1911, further carried out wilting point experiments, using moorland species to estimate the amount of water available to the plant in moorland soils. The amount of water remaining in the soil after the plant had wilted, namely, the "unavailable" water, was stated as a fraction of the original amount of water present. These figures varied from 1/3 unavailable water to Molinia, Erica tetralix and Pteris to 1/9 unavailable to Eriophorum species. Discussing the unlikelihood of 'physiological drought' in moorland species, Priestley (31) 1924, showed that moorland water is non-toxic to plants, and that the ratio of leaf area to root in ericoid species is comparable to that in normal mesophytes. The root structure and metabolism are, however, as a result of water-logging and low calcium in these soils, adapted to the conditions of poor aeration. Pearsall (28) 1950, in a paper on the property of wet soils /

soils and their agricultural significance, asserted that the main effect on the vegetation was the lack of aeration and the consequent prevalence of reducing conditions. These are associated with the liberation of larger amounts of iron, manganese and aluminium cations which are toxic in concentration to many plants. Pearsall and Wray (29), 1927, point out that Calcium-sensitive species such as Eriophorum angustifolium, could tolerate much higher concentrations of calcium in the soil solution if the soil humidity were increased. The effect of a water-logged soil on the advance of Pteris aquilina has been shown by Poel (30), 1951. Aeration, he showed, was necessary for the survival of this species, and where reducing conditions obtained, it died.

Hubbard (17), working with the distribution of grass species, correlated these species with the clay percentage of the soil. This he used as an indirect correlation between species and water as, other conditions being similar, the clay percentage was an approximate indication of the soil's water-holding capacity. Colvin et al (2) 1942, in a paper on the distribution of herbaceous plants and shrubs in relation to the soil water-holding capacity, indicated that the different powers of retention by the various soil horizons, had some bearing on plant occurrence. He added a list of American species to support his view. Following a parallel line of investigation,

investigation, Heath and Luckwill (16) 1938, discussed the rooting-systems of heath plants. Estimations of water and humus contents were made at depths of 4, 15, and 23cms. below typical heath species, and on the basis of these results and root profiles, they identified three main types of rooting system.

With regard to hill species, the usual method of soil water estimation depends on the height of the water table in relation to the soil surface. Normally this level fluctuates with the season, being lowest in summer and highest in winter. In certain ciscumstances, the rising of the water table above ground level in winter has a controlling effect on vegetation. Jeffreys (19) 1916, reports that Nardus stricta will not colonise areas liable to winter flooding. The same author (18) 1917, finds similar results for Agrostis, Calluna, Deschampsia flexuosa and Ulex. It is apparent that in comparable soils, the height of the water table could be used as an indicator of soil "wetness", but as a means of comparing peat communities in relation to soil water, it is doubtful whether the water table level is of much diagnostic value. Thus Olsen (27) 1925, discussing a transition from Low to High moor across various plant communities, stated that the water table was in all cases 30 cms. below the surface of the soil, and that "Moisture conditions cannot be of any importance to the plant distribution." Certainly in the writer's/

writer's experience, wide differences have been found in W/H ratios for top soils where, in the course of digging profiles, no trace of a water table was found. Describing an experiment on the growth of crop plants on peat, Kirsanoff (23), 1926, found that in soils waterlogged during the dormant season of growth, the yield was inversely related to the height of the water table in the peat. Thus it would appear that prolonged waterlogging of the peat had an effect which was not immediately removed when the peat dried out.

In his classic paper on the ecology of Molinia caerulea, Jeffries (20) 1915, showed that not only was the amount of water in the soil important, but also whether it was moving or stagnant. Molinia was found where water was moving and, where the fall was under 1 in 18 leading to stagnation, Eriophorum became dominant. McVean (26) 1952, in a paper on the ecology of Molinia pastures, commented that the water movement could be either horizontal or vertical, and that invasion by Polytrichum commune accompanied stagnation or mineral impoverishment.

Apart from those authors noted above, many others have mentioned, without recording accurately, the occurrence in both dry and wet situations, of hill species. No quantitative method seems to have been used to estimate the amount of water present, but their observations, taken in the mass, provide considerable evidence that there is a definite relationship between hill-plant communities and water./

water. Reports with a bearing on this relationship, are given by the following:-- Conway(3) 1949, Davies (7), 1944, Evans (8), 1932, Farrow (9) 1915, and (10), 1917, Fritsch and Parker (11), 1913, Godway and Conway (12), 1939, Harley and Yemm (15) 1942, Jeffreys (18), 1917, and (19), 1916, Jowett and Scurfield (21), 1949, Lewis (25), 1904, Smith, (32), 1903, Woodhead (34), Watkins (33), 1950.

Coefficient of Humidity figures for communities as sampled by the writer, are also given by Crump (4)1911, Haines (13), 1926 and Jeffreys (18) 1917, and will be discussed later.

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EXCHANGEABLE CALCIUM

LITERATURE REVIEW

As was shown when discussing soil hydrogen ion concentration, a low pH is usually associated with a low amount of soil calcium. On the strongly leached soils of the Southern Uplands of Scotland, Ca is very low except in flush areas where the percolating waters are relatively high in minerals. These areas have a higher pH and base content, and, in marked contrast to the normal poor vegetation of upland pastures, are colonised by broad-leaved species and white clover.

Priestly and Hinchcliff (12) 1922, in a paper on the physiological anatomy of vascular plants growing in peat, showed that these were all high in fats, and had anatomical features such as thick cuticle and secondary endodermis. This was due to their form of metabolism in sour soils which were poor in oxygen and calcium. In a discussion of the ecology of moorland plants, Priestly (14) 1924, elaborated this discovery and suggested that the injurious effect of a high calcium supply to these species resulted from the reaction between calcium and the fatty acid in the root, forming insoluble soaps. This prevented free translocation from the root to the aerial parts . Similarly, Pearsall and Wray (13) 1927, discussing the calcifuge habit, showed that increasing soil pH and thus the calcium absorbtion, inhibited root growth. The

The same authors (12) 1927, in an experiment using Eriophorum angustifolium, found optimum growth in bog water where pH, calcium and base ratio were all low. They also observed that increased temperature or humidity reduced the calcium effect on calcifuge species. Rayner (14) 1921, in her report on the calcifuge habit of Calluna vulgaris showed that increasing the calcium content changed the role of the endophytic root fungus (always associated with the roots of Calluna) from symbiosis to that of a parasite, seriously reducing the plant's vitality. Thus for the true moorland species on peat, with their specialised metabolism and mode of growth, the very low amount of exchangeable calcium available to them in many ways, is an advantage rather than a hindrance.

In the other broad division of Upland vegetation, termed by Tansley (20) 1949, the "Acidic Grasslands" as distinct from moorland, conditions of growth are not wholly comparable to those just described. This type includes formations dominated by Agrostis-fescue, Nardus, Deschampsia flexuosa, Molinia caerulea and Pteris aquilina. Jowett and Scurfield (8) 1952, showed that the base requirement of Deschampsia flexuosa was low, though Olsen (11) 1938, in a paper held that the same species had a wide tolerance of the amount of calcium present so long as the pH remained low. Ogg and Dow (10) 1928, found that, on analysis, the soil supporting Calluna, Nardus and

and Ulex and poor grass (Festuca ovina) gave very low amounts of exchangeable calcium, (less than 0.1%) which increased under an Agrostis-Holcus type, while the highest figures for the hill soils came from the flushes. This finding agrees with exchangeable calcium figures under Vaccinium myrtillus given by Thomas (28) 1938.

Discussing the distribution of calcicoles and calcifuges in relation to Soil Calcium Carbonate, De Silva (2) 1934, pointed out that exchangeable calcium played an important part in the distribution of Vaccinium, Luzula and Mercurialis. He also discovered that, under similar pH conditions, differing amounts of exchangeable calcium were reflected in the vegetation; and further, that Pteris aquilina was distributed more in relation to pH than to exchangeable calcium, a result similar to that found for Deschampsia by Olsen (11) 1938.

One of the most striking effects produced on hill soils by increased Calcium and reduced acidity is the markedly different vegetation of flushes from that of the surrounding unflushed area. An interesting series of experiments was conducted by Heddle and Ogg (6) 1933 and (7), 1936 on the change brought about in hill vegetation by artificial flushing with spring water. In each case, the reduction of acidity and the increase in exchangeable calcium percentage was accompanied by a change in vegetation. Generally, Agrostis species and Festuca rubra increased while the typical acidic

acidic grassland sps, species, such as Deschampsia, Nardus stricta, Festuca ovina and Galium saxatile, decreased. It would thus appear that, unlike the specially adapted moorland species, the acidic grassland types occupy one end of the acidity-calcium range of the normal Mesophytes. These are superseded by better species when soils conditions improve, even though the original species, in the absence of competition, could still grow in the new conditions. Exchangeable Calcium therefore, plays a significant part in the distribution of upland species.

Few estimations have been made of exchangeable calcium content of hill soils. Some are however available and are reported by Heddle and Ogg (6) 1936, Ogg and Dow (10), 1928, Smith (17) 1925, and (18) 1928, and as Thomson (20) 1933. Haines (5) 1926, though giving no calcium figures, related vegetation type to total salts present, and Fraser (3) 1933, gave figures for calcium from peat types characteristic of moorland species.

Cooper (1) 1932, stressed the importanse of ~~%~~ percentage base saturation of the soil as a factor governing the distribution of plants, a deduction borne out by the work of Gorham (4) 1953. In this, he showed that the typical Molinia/Schoenus vegetation of the Irish bogs, compared with the Sphagnum-Calluna vegetation of their British counterparts, is due to the higher base saturation of the peat in Ireland. This suggests that Jeffries(9) 1915, (who made no no soil analyses) was correct in his view that Molinia demanded a relatively higher salt concentration in the soil than most other moorland plants.

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7.	Heddle and Ogg.	1936	J. of Ecol	Vol.24	p.220
8.	Jowett and Scurfield	1952	" " "	Vol.40	p.393
9.	Jeffries T.A.	1915	" " "	Vol.3	p.93
10.	Ogg and Dow	1928	" " Agric. Sc.	Vol.18	p.131
11.	Olsen C.	1938	Com. Rend.Lab. Carls.	Vol.22	p.405
12.	Pearsall and Wray	1927	J. of Ecol	Vol.15	p.12
13.	Pearsall and Wray	1927	" " "	Vol.15	p.1
14.	Priestly J.H.	1924	Nature	Vol.114	p.698
15.	Priestly and Hinchcliff	1922	The Naturalist	Vol.	p.263
16.	Rayner M.C.	1921	J. of Ecol	Vol.9	p.60
17.	Smith A.M.	1925	J. of Agric Sc.	Vol.15	p.466
18.	" "	1928	" " "	Vol.18	p.68
19.	Tansley A.G.	1949	The British Islands and their Vegetation		
20.	Thomas B.	1938	J. Min Agric.	Vol.45	p.546
21.	Williams R.	1928	J. of Agric Sc.	Vol.18	p.439

SECTION 2

SOURHOPE - SOILS

S O I L S

This section is devoted to a resumé of the Macauly Institute report on the soils of Sourhope. The original survey was on a scale of six inches to one mile, but has been reproduced here on the three inch scale. (Map 1)

Throughout this thesis the term "peat" refers to partially decomposed plant material formed under anaerobic conditions. Thus type VII A and B are peats, in contrast with the sites at Heatherhope and Type V on Sourhope, where the organic layer will be referred to as Mor humus.

Sourhope - Distribution of Peat

Although situated in an upland region rising to 2,000 feet, only a relatively small acreage is covered with peat. The reason for this is obscure: three miles to the south the main mass of The Cheviot is largely peat covered, and a similar distance to the west, at Heatherhope in the head-waters of the Kale Water on hills of much the same general height as those of Sourhope, Mor humus covers large areas. This may in part explain the almost complete absence of heather (Calluna vulgaris) on Sourhope when compared with the large tracts of heather to be found on Cheviot and at Heather-hope.

From the soils map on page 83 the main peat area is denoted by the colour purple. (Type VIIA).

/

Photo. 7. (Sourhope - Height 1700 ft)

This photograph shows the overgrown peat hags on the top of the Birnie Brae. Heather is almost absent though in many parts the peat is very deep.

Photo. 8. (Heatherhope - Height 800')

This photograph shows a hag-edge at Heatherhope. The organic layer is thin, the heather vigorous and little dissection by erosion has taken place.

Photo. 9. (Cheviot - Height 2,500')

This photograph shows the extreme dissection of the peat on the flat summit of the Cheviot. The vegetation is dominantly Calluna vulgaris.

(Type VIIA). The peat here is 2 - 6 feet deep and probably represents the last remnant of the old peat surface which at one time would extend much farther down the hillsides. At the present day no very active erosion or hagging of the peat is taking place, the old hag edges being completely overgrown with vegetation (See Photo 7). This contrasts sharply with the extreme erosion taking place on Cheviot, as can be seen in Photo 9 ~~xxx~~ and Heatherhope (Photo 8), though in the latter locality hagging is not so severe. Peat over 1 foot in depth was also found by the writer on the gentle easterly slope on the summit of the Dod (Site 30, Map 2) and north-east of the summit of the Schil (Site 5, Map 2). The only other deep peat present is of the basin type overlying clay till (Type VIIB, Map 3, shown in light purple.) The writer would also include in this type the flat, boggy area between the Rowantree and Dod Burns marked on the Soils Map as Type I. Deep peat is also present over an appreciable area 10 yards south of Field 12, between the Dod Hill and the Park Law, dominated by tussocky Molinia and Eriophorum species.

Type V, coloured red on the Soils Maps, is confined to the northern part of the farm. The raw mor is black and greasy, but is seldom over 8 inches in depth. South-west of the summit of The Curr at Site 46 the writer found the profile to have 12 - 14 inches of black, amorphous, crumbly humus, /

humus, and suggests that this area should have been included in Type IV.

Type VI, coloured orange, is the most extensive of the highly organic soils found on Sourhope. The organic layer is from 2 - 14 inches thick and is composed of a black, amorphous, crumbly mor humus of a different type from that found in Type V or Type VII. The Type is further represented at Site 10 (Park Law) and Sites 37, 15 and 42 on the Hairny Law as borne out by the profiles for these areas, but not indicated as such on the Soils Map.

<u>Sourhope - Distribution of Mineral Soils</u>

The Soil Survey has divided the Mineral soils into four main types.

<u>Type I</u>: (deep clay loam tills) - has three members represented by three shades of green. The soils are all damp and show various degrees of mottling in the soil profile. The till is at least 4 feet thick and is derived from porphyritic lava. Type IA is found on the steeper valley slopes, IB where the slopes flatten out and IC at the bottoms of the slopes. All are to some extent flushed by spring water. The drainage becomes progressively poorer from IA to IC, the gley horizon in A being at 21 inches, in B at 10 inches, and in C at 7 inches. Worms though present in A and B are not found in C, while B and C have a 1 inch sub-surface layer of well decomposed mull humus. /

humus.

<u>Type 2</u>: (Stony loam till)- has two members shown in two shades of blue on the map. In 2A the till is at least 4 feet deep: 2B is a very stony loam till with the solid rock approximately 30 inches from the surface. The slope in both members is moderate to steep, and this type occurs at a higher altitude than Type 1. A has a half inch layer of mull humus below the surface litter and slight ochreous staining at depth. B has 5 inches of dark brown organic matter mixed with some inorganic material and stones. In both members drainage is moderate.

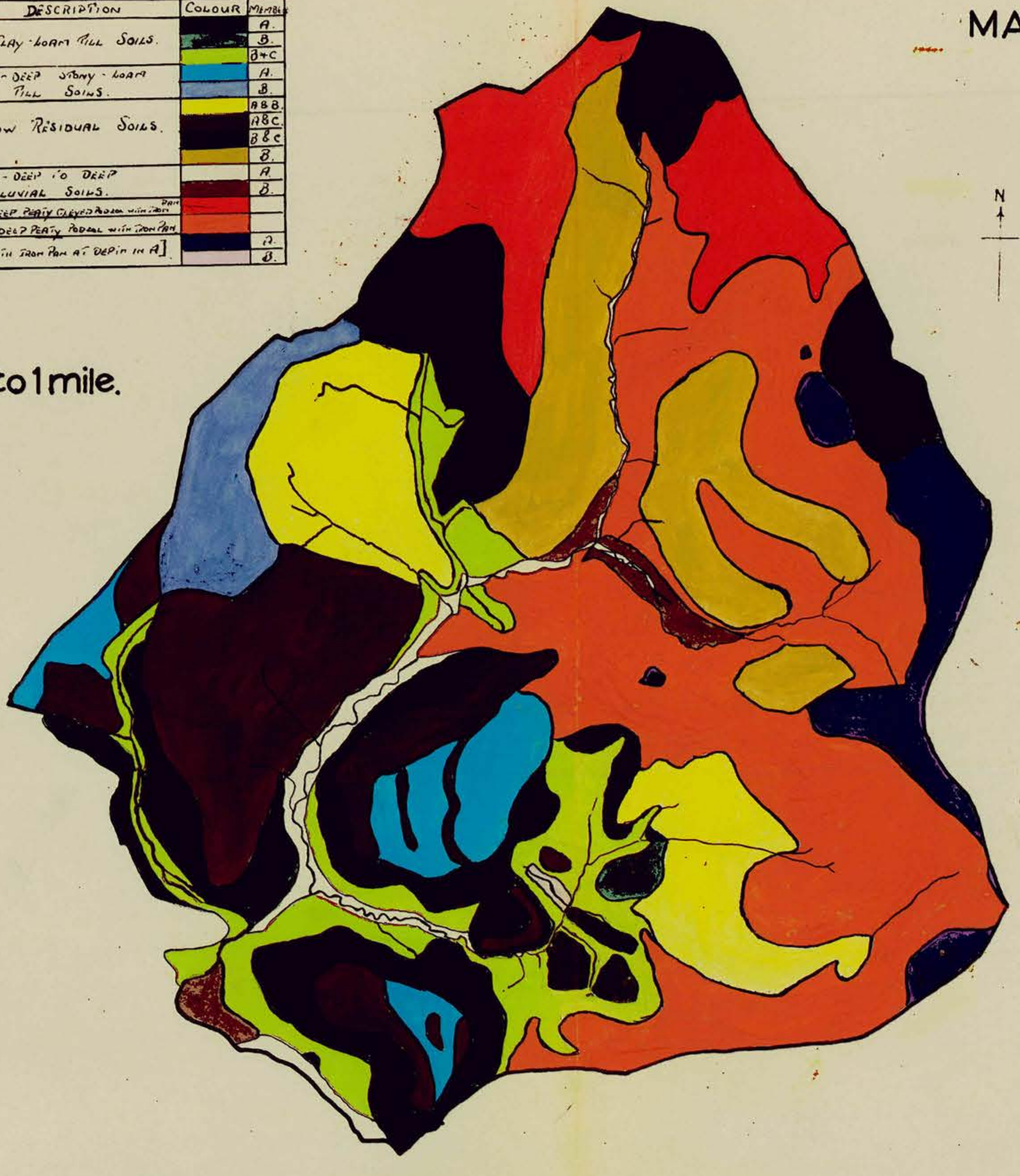
<u>Type 3</u>: (Residual soils)- has three members shown in yellow, dark-brown, light-brown and black on Map 1. All are derived from residual lava material, 3A and 3B being located on steep hill slopes and 3C on the top of lava knolls. The soils are all very shallow, reaching their deepest at 18 inches in A. 3B is scree and occurs on the steepest slopes. A may contain mixed till and has a 1 inch sub-surface mull humus horizon. C on the other hand has 5 inches of dark brown organic matter below the litter layer. This material is reasonably pure apart from some angular stones and small boulders. The parent lava joint blocks are reached at 16 inches. The drainage ranges from moderate in 3A to excessive to good in 3B and C.

Type 4: Medium to deep alluvial soils - shown in white and sienna on the map, has two members. This is the smallest type on the farm, A being stream bottoms liable to flooding while B are terraces above the flood level. A shows 12 inches of medium-brown gravelly sandy-loam resting on gravel. B has 6 inches of black, well decomposed granular humus below the litter layer and a thin iron pan at 16 inches. Drainage in both members is moderate.

MAP 1.

Type	Description	Colour	Member
I.	Deep Clay-Loam Till Soils.		A.
			B.
			B+C
II.	Medium-Deep Stony-Loam Till Soils.		A.
			B.
III.	Shallow Residual Soils.		A&B.
			A&C.
			B&C
			B.
IV	Medium-Deep to Deep Alluvial Soils.		A.
			B.
V.	Medium-Deep Peaty Gleyed Podzol with Iron Pan		
VI	Medium-Deep Peaty Podzol with Iron Pan		
VII.	Peats [with Iron Pan at Depth in A]		A.
			B.

3 ins. to 1 mile.



SOURHOPE FARM — SOILS MAP

Sampling Method for Soils.

At the commencement of this work, difficulty was found in ascertaining the number of soil samples which it was necessary to take within an area; the mean of whose analyses would accurately represent the prevailing soil conditions. The available hill-soil literature makes no reference to this subject, and it was thought advisable to err on the safe side by taking too many samples for each site rather than too few. The nature of the work also precluded the use of a fixed size of sampling area -- this being determined by the extent of the plant association. The associations sampled were considered to be well-established, thus having soils which would show characteristics peculiar to the vegetation they support.

In each main soil-site sampled, three soil profiles were dug. These profiles were taken ten to twenty yards apart, the three either forming a straight line or a triangle, depending on the shape of the plant association. Where possible, the profiles were dug to a depth at which there was likely to be no further change in soil type-- the parent C horizon-- a procedure facilitated in many cases by the shallowness of many hill soils. In a few cases however, a layer of large stones, the flooding of the hole by ground water, or the presence of very deep peat prevented the exposure of the complete

complete soil profile. In the profile diagrams, incomplete profiles resulting from the above causes, are marked accordingly.

For each profile, two samples were taken--one from the top 5" of soil, excluding the litter layer, and one from the parent subsoil. Great care was exercised in taking the soil samples to prevent contamination. A further seven soil samples were taken at random by trowel over the site. The litter layer was removed, and a plug of soil 5" deep and 4" in diameter was removed for analysis. Thus for each main site, ten surface and three subsoil samples were analysed. Anexamination of the number of soil samples taken for each site will sometimes show that in fact, fewer than ten samples were taken. This was done when the association, though appearing typical, was less than the minimum size for complete sampling. Fewer than ten samples were also taken in one site when the results were being used to show whether any change took place in water content, etc. at different times of the year. To prevent loss of water in transit, soils were transported to the laboratory in water-proof lined bags. The various methods of the analysis for each soil factor are detailed in the Appendix 1V.

It is not within the scope of this work, nor was the field work planned, to determine a technique of sampling hill soils. Information of this nature would have been of great value to the writer. Two methods of sampling were considered: firstly, that

that described above, and secondly, random selection of one or two soil samples from a very small area of say, one square metre. An accurate vegetational analysis of the whole sampling area could thus be related to the chemical analyses of the two samples. Had it been the intention to compare fine differences in chemical analysis with minor changes in vegetation, (as would have been the case, were it the intention to explain the presence or absence of a particular species in a specific community) this undoubtedly would have been the method chosen. The work however, was designed to show whether any obvious differences did exist between the soils favouring the growth of the main types of hill vegetation. Fot this reason, it was decided that the results obtained by the first method would prove more rewarding as a means of comparison, than those that could be obtained by the second method.

SECTION 3

SOURHOPE - VEGETATION

SOURHOPE - VEGETATION

Sourhope Farm is situated on land locally termed "white". The reason is that Calluna vulgaris, apart from a few degenerate patches on the top of the Birnie Brae and around Site 47 on Auchope is almost unrepresented. By far the largest area is covered by grass species.

On the wetter slopes, where spring water is absent, Molinia caerulea dominates, covering large areas of the Birnie Brae, The Dod, the north-east slope of the Park Law, the Hairny Law and Fasset. This species is always associated with a layer of black, amorphous, granular mor humus.

On the lower slopes and where springs occur on the hillsides, Agrostis-fescue is the main vegetation type. The effect of spring water is very clearly shown by the vegetation on the east slope of Fasset. Above the spring line is Molinia; below is Agrostis-fescue with narrow tongues of Molinia projecting into it wherever the lie of the land makes flushing by spring water impossible. The boundary between the communities is very sharp. The transition can be seen in many places throughout the area investigated, and it may be safely assumed that wherever this community is found, flushing by spring water is taking place. On the lowest slopes and where gleying takes place (see page 111), the Agrostis-fescue type becomes wetter, as evidenced/

evidenced by an increase in the amount of Deschampsia caespitosa. This latter species becomes dominant in a few, small, very localised areas. For the purposes of this thesis, owing to the difficulty of laying down hard and fast limits for each association and to the fact that both are dependent on a supply of relatively base-rich spring water the wetter Deschampsia caespitosa association is treated as a facies of the Agrostis-fescue community. Unlike the afore-mentioned Molinia community which is grazed by sheep only during June and July, the Agrostis-fescue type is grazed at all times of the year, but particularly in the autumn, winter and early spring.

On the thin soils of the rocky brows and knolls and on the very steep slopes of the Park Law, Dod, Hairny Law, Shorthope, The Banks, Fasset, and Kaim Knowe, the main vegetation is of the Deschampsia flexuosa - Festuca ovina type. The soils are characteristically very dry and snuffy with many stones and rock fragments. The situation of this type leaves it exposed to atmospheric conditions and, owing to hill wash and gravitational slipping to the more gentle slopes below its soil is unstable. The habitat is perhaps the most exacting and rigorous of any found in this district.

As has already been mentioned, Calluna vulgaris is not one of the major vegetational dominants found on Sourhope. It is, however, a species/

species which does occupy a considerable area of the surrounding country, and as such, it is included as one of the vegetation types investigated in the course of this work. The areas from which the samples were obtained are shown on the Ordnance Survey map on page 104. The absence of heather on the Sourhope hills may be the result of grazing, burning, or of some other factor as yet unknown. What heather remains is of a degenerate or very wet type. It may be surmised that the severe hagging and erosion of the peat on Cheviot (see Photo 9.) and the remains of peat hags on Sourhope (see Photo 7.) indicate that peat at one time covered a much larger area than it does at the present day, only a few remnants on the flatter hill-tops now remaining. Whether this original peat-cover would support a heather vegetation, ~~however~~ though probable, is uncertain.

The final main vegetation type is that dominated by Nardus stricta. This species has a wide range of habitat and is found as a subsidiary species in nearly all the other main vegetation types. During the selection of sites for sampling, the presence of tufts of Nardus was taken as an indication of instability in the plant association - and communities showing this were thus considered non-typical examples. For this reason, wherever possible, such "transitional" associations were avoided, as can be seen from the vegetation /

vegetation analysis figures for the Deschampsia flexuosa and Calluna vulgaris types. In the cases of the Molinia and Agrostis-fescue types, however, it was found that associations containing no Nardus were rare, particularly with respect to Molinia, and it is now the writer's opinion that this species, in small amounts, is a normal constituent of these vegetation types, and does not necessarily imply that the association is degenerating or is transitional.

The Nardus community covers large areas on the lower slopes of the Dod and Park Law, the flat tops of the Park Law, Fasset and Hairny Law. Smaller associations may be found on the Gairs, Rigg, Shorthope and Auchope. The Schil is almost entirely covered by a dry, stony, Nardus - Deschampsia flexuosa type. Appreciable quantities of Nardus are also found on the old river terraces of the Sourhope and Kaim Burns.

To a much lesser extent six other communities are represented. Of these the largest is the Pteridium aquilinum or bracken type found on the lower slopes of the Dod, east face of the Fasset, Hairny Law, Shorthope and Park Law. It is, in all cases sparse, thick bracken being found in only a few very small patches. It is most common on soils supporting vegetation of the Agrostis-fescue and Deschampsia flexuosa types. On the east slope of Fasset, crescent-shaped associations of /

of bracken colonise the ground above the exit of springs, and bracken-rings, probably similar to those described by Watt, can be seen on the lower slopes of the Dod (see Photos 1 and 2.). The general low density of the bracken and the absence of associations where Pteridium was truly dominant, excluded this community from those to be investigated. Of the very wet communities, Carex spp. become locally dominant on the wettest part of flushes; and where ground water collects or drainage is impeded, the ground is colonised, in many cases almost exclusively, by Juncus communis. This latter species is common along the lines of choked drains and on the bottoms of the flat valleys liable to flooding when the streams are in spate. Of the wet heath species, Eriophorum vaginatum is a common associate, attaining in a few limited areas sub-dominance to co-dominance. Within the bounds of the farm, however, no vigorous Eripphoretum exists. Vaccinium myrtillus - the blaeberry - though a common subordinate species in many of the plant associations, nowhere attains dominance. In only one area is it found in the role of co-dominant - on the very steep upper slopes of The Banks (Site 49, Map 2, page 103) - at a height of 1,250 feet, where dominance is shared with Nardus. As this species is of importance in upland pastures, this association was sampled. The results are included with those /

those of Nardus. The only other community wotthy of note is that containing Ulex europaeus. The distribution of this species is very limited, and it occurs always below 800 feet. It is confined to two small areas on the steep lower slopes of the Hairny Law and to one area on the steep south face of the Kaim Knowe. The soil is dry and stony and is of the Deschampsia flexuosa type.

The only natural tree species represented on the farm is the hawthorn (Crataegus monogyna, Jacq.). Two specimens grow in the steep, stony, colluvial soils on the south face of the Park Law and a few more small stunted specimens on the steep screes on the south-west face of Fasset. No tree seedlings of hawthorn or any other species were recorded at any place on the farm.

SOURHOPE - History of Forest Cover and Grazing.

Reliable reports and records concerning the past vegetational and grazing history of the Cheviot Hills are few. Research by King, however, into old abbey and manse records has brought the following information to light.

The Sourhope area has been inhabited for at least 2000 years, the earliest indications being the walled home-steads said to be of Cambro-British Age. A well preserved example crowns the summit of the Park Law, Fasset and Gairs. It may be assumed that the scrub woodland which occupied such summit sites would be cleared by these early peoples who would possess a certain number of cattle. The grazing of these animals would inhibit woodland regeneration on the cleared areas. The area cleared would thus be gradually extended to the valleys, and it may be assumed that the more accessible hills such as the Park Law and the Fasset, have been under some form of regular grazing since the 10th century.

From the 10th century onward, the area under woodland in the less accessible parts, which may have included Auchope, was gradually cleared of trees and scrub and by 1560, little of the original tree cover remained. From 1560, the grazing intensity increased in all parts and from 1750, the characteristic southern upland type of /

of sheep farming more or less in its present day form has been carried on. The available evidence also shows that the sheep carrying capacity per acre has shown little or no change in the last 200 years.

A much fuller and more detailed account on this subject may be found in Mr King's thesis, which will be submitted within the next six months.

METHOD OF VEGETATION ANALYSIS.

At the commencement of this work some investigations were made into the various methods of assessing and recording the species present in a plant community. Various factors had to be taken into account. The method selected had to be reasonably accurate, particularly with reference to the dominant and sub-dominant species, and at the same time it had to be speedy, and not necessitate the use of heavy or cumbersome equipment.

Estimation methods were the first to be ruled out, it being considered that much experience was necessary before reliable estimates of botanical composition could be made by eye. This applies particularly to the dense hill grassland associations comprising many fine-and broad leaved species. Tufts and tussocks composed of two or three species are common, making estimations of the amount of each species present in the sward a matter of some complexity. Methods based on charting, percentage productivity and percentage ground covered were also considered, but in practice were deemed unsuited to the type of vegetation, and too elaborate and time-consuming for the use for which the results were required.

It was thus decided that a Specific Frequency method should be employed as discussed by /

by Raunkiaer (1), 1918, & Stapledon (2), 1912. This method is speedy and gives a reasonably accurate estimate of botanical composition. Not only so, but, of all the methods tried, results are least affected by seasonal variations in the herbage, a factor of importance, when the short season of growth of most of the hill species is taken into consideration.

Though the Specific Frequency method is of little direct value as a means of quantitative analysis, it has been shown by Ashby (3), 1935, that, where the distribution of the species is random, the chance of the occurrence of a given species in a quadrat can be related to its density. Also, Blackman (4), 1935, & (5) 1942, states that, $\log_{10}$% absence of a species can be correlated with % area cover; and further, even where the distribution is not random, an approximately linear relationship exists between $\log_{10}$% absence and density. Thus the data obtained for botanical analysis using the Specific Frequency method can be related to density and % area cover. Botanical analyses using the Point Quadrat have been carried out for some years on the hill vegetation of Sourhope Farm. It has been found, however, that the use of this method, which is essentially a specific frequency one, has certain disadvantages. Among thes is the large number of observations necessary and the sensitivity of the method /

method to herbage length. This latter factor is a serious one when the results are to be used to compare different plant communities, the nature of the work precluding the analysis of the sites at the same time of year.

When sampling grassland of high density, Archibald (6) 1949, showed that a quadrat of 25 sq. cms. or less is required. This small size of quadrat ensures that the species are spread over the frequency scale. For this reason the 25 sq.cm. quadrat was used by the writer.

Consideration must be given at this stage to the number of throws of the quadrat necessary to give results which would characterise the plant community under investigation. Nielen & Dirven (7) 1950, using a 25 sq. Cm. aquadrat, conclude that 100-120 quadrats are necessary. With this number of throws, they show that a species having a frequency of 25% has a Standard Error of about 25% i.e. 25 + or - 6. King, (8), working on a Festuca ovina - Deschampsia flexuosa community of one twelfth of an acre found that the 25 sq.cm. quadrat gave the best separation of species. He further showed, using the same size of quadrat, that species with a mean frequency of 40% show a variation for groups of 20 quadrats of 25 - 30% of the mean, i.e. 40 + or - 10/12. For a frequency of 10% the variation was 50 - 60% of the mean i.e. 10 + or - 5. At these low frequency levels /

levels variation thus tends to be high, though it is possible that a variation of 5 - 15%, (10 - 5) where the species is of such low occurrence, is of little practical importance. As the specific frequency increases, the variation decreases, and over 60% S.F. any change that would take place as the number of throws increased, would be very small. Archibald, (6) 1949, used 20 quadrats or throws to examine a variety of communities.

While 20 quadrats is insufficient to measure accurately small differences in communities belonging to the same plant association, it was considered sufficient for the present purpose. The figures obtained provide a means of ensuring that each community is, indeed, an example of one of the five major vegetation types investigated, and of grouping the sites with a view to comparing the soil conditions in each. It must be stressed that the accuracy of the vegetation analysis figures is such, that comparison of the differing amounts of subsidiary species having low percentage frequency figures with particular soil characteristics, must be undertaken with caution.

Methods of Vegetation Analysis. - Literature.

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2. Stapledon, R.G. 1912 Jour. Agric. Sc.Vol.5, p.129.
3. Ashby, E. 1935 Ann, Bot. Vol.49, p.779.
4. Blackman, G.E. 1935 Ann, Bot. Vol.49, p.749.
5. Blackman, G.E. 1942 Ann, Bot. Vol. S.N.S. p.351
6. Archibald, E.E.A. 1949 J. of Ecol. Vol.37, p.260.
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8. King, J. 1953 Private communication.

SECTION 4

DESCRIPTION OF VEGETATION TYPES

GRID REFERENCES FOR VEGETATION SITES. MAPS 2 & 3

Agrostis (1).

6 239047
8 243016
9 247032
44 247018
51 233013

Agrostis (2)

39 253038
40 244031
45 248022
48 239015
50 241021
59 814220 O. S.

Calluna (1)

47 251093
56 929232 O.S.
57 924229 O.S.
61 271038 ~~O.S.~~

Calluna (2)

52 859172 O.S.
53 810165 "
54 813158 "
55 802168 "
58 906228 "
60 825187 "

Nardus (1)

13 251032
19 236031
20 234039
22 239016
36 228024
38 216024
63 233052

Nardus (2)

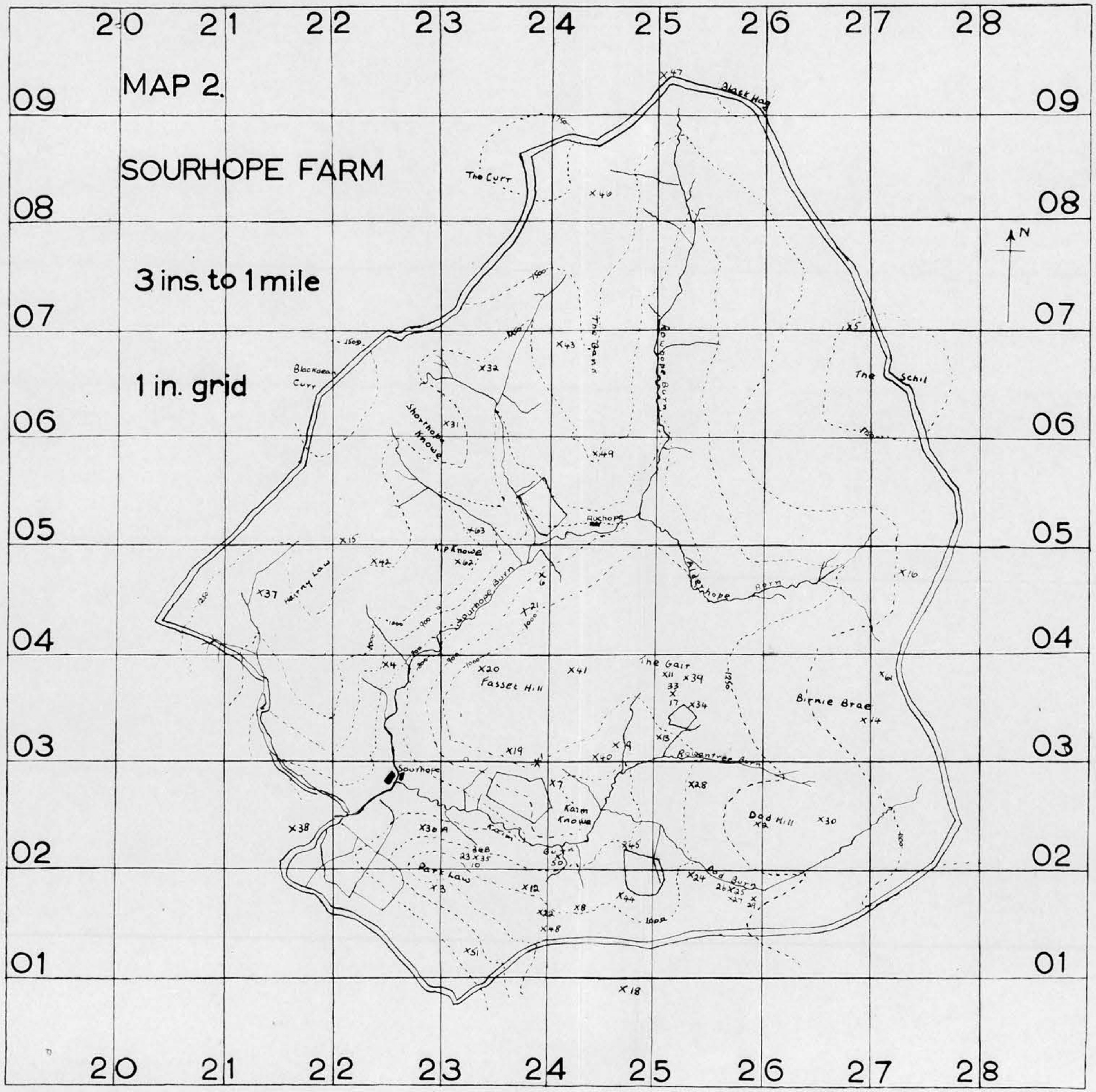
5 268071
14 269034
15 221051
43 241069
46 244083

Molinia

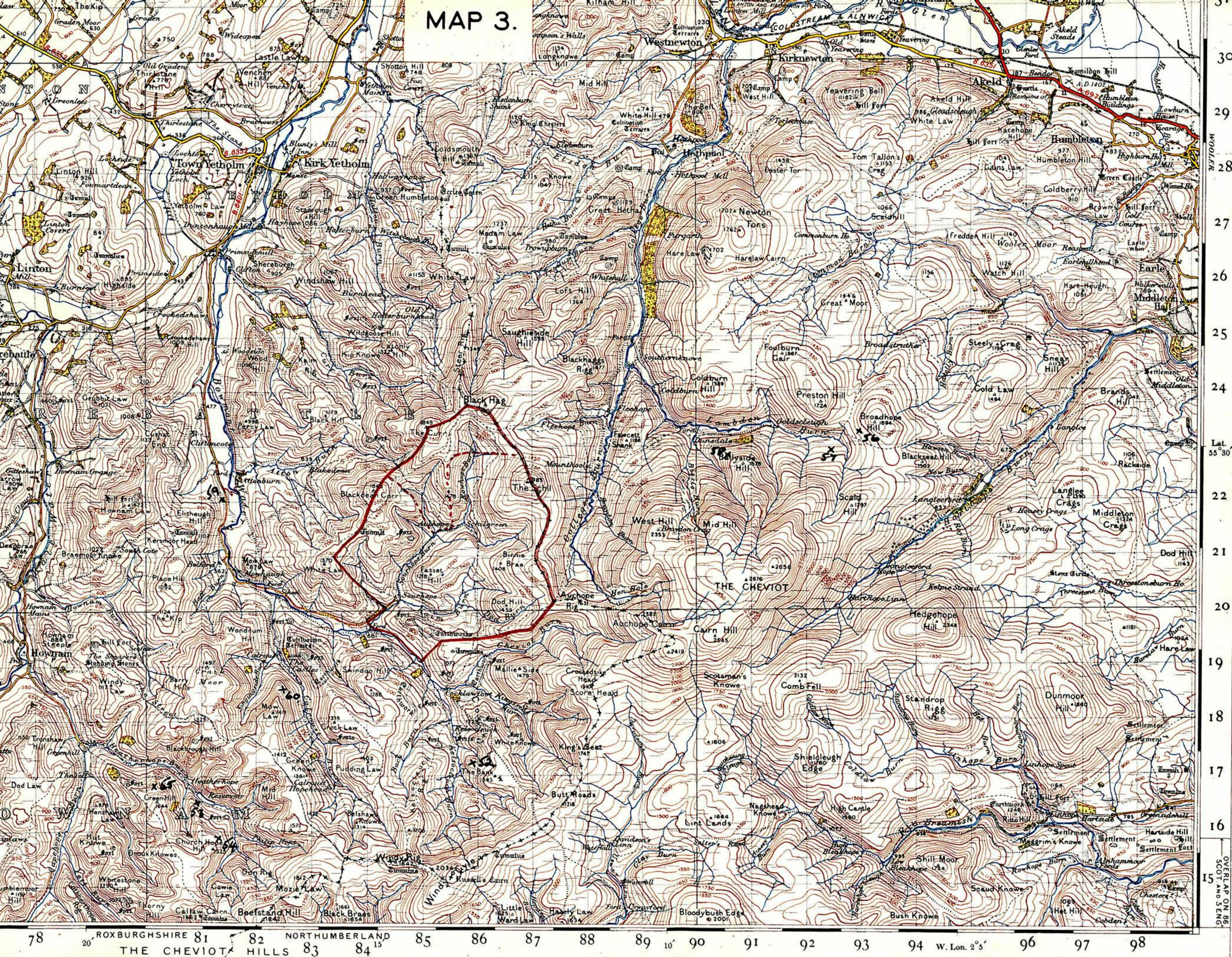
10 233021
11 251038
12 238018
17 252037
37 213046
41 242039
42 224049

Deschampsia

1 239030
2 259024
3 229018
4 225039
7 241028
62 232048.


MAP 2.
SOURHOPE FARM
3 ins. to 1 mile
1 in. grid
20 21 22 23 24 25 26 27 28
09 08 07 06 05 04 03 02 01
N
Black Hag
The Curr
Blackdean Curr
Shorthope Knowe
Auchope
Kip Knowe
Hairny Law
Sourhope Burn
Auchope Burn
Alderhope Burn
The Schil
The Gait
Fasset Hill
Birnie Brae
Sourhope
Rowantree Burn
Karm Knowe
Dod Hill
Park Law
Dod Burn

MAP 3.


THE CHEVIOT HILLS
ROXBURGHSHIRE
NORTHUMBERLAND
THE CHEVIOT
Town Yetholm
Kirk Yetholm
Kirknewton
Westnewton
Akeld
Humbleton
Hethpool
Black Hag
The Curr
The Schil
Auchope Rig
Auchope Cairn
Cairn Hill
Hedgehope Hill
Comb Fell
Newton Tors
Preston Hill
Coldburn Hill
Mid Hill
West Hill
Hownam
Linton
Windy Rig
Bloodybush Edge
Shill Moor
Dunmoor Hill
Yeavering Bell
WOOLER
COLDSTREAM & ALNWICK
OVERLAP ON 86 SCOT AND 5 ENG
W. Lon. 2°5'
Lat. 55°30'

AGROSTIS - FESCUE TYPE

The Agrostis-fescue vegetation type is well distributed over Sourhope Farm although the amount of ground it occupies is relatively small. It is confined entirely to soils which are subject to some form of flushing by spring water. The communities normally take the form of a fan with the spring at the apex. Where the effect of the spring water lessens, the vegetation becomes "rougher", the better grasses being replaced by Nardus stricta, Anthoxanthum odoratum and other moorland grasses. Deschampsia caespitosa can be treated as a constant species, being present in varying amounts in all the sites but one. It was thus considered that this species, even where dominant, should be included in the Agrostis-fescue type, its habitat and soil differing as shown by the results in little more than the amount of water present. To aid the discussion of these findings, however, it has been found convenient to group the sites with reference to the presence or absence of gleying in the soil profile (see page 119).

<u>Type 1</u> - Sites 6, 8, 9, 44 and 51.
No gleying present.

TABLE 1.

VEGETATION ANALYSIS

	Site				
	6	8	9	44	51
Agrostis spp.	95	100	100	100	95
Festuca ovina	60	100	65	85	30
Deschampsia flexuosa . ..	-	5	20	10	65
Anthoxanthum odoratum ..	55	65	20	40	30
Poa pratensis	30	25	10	25	5
Holcus mollis	20	80	30	15	-
Festuca rubra	60	-	45	40	5
Nardus stricta	-	10	20	-	60
Galium saxatile	5	35	55	80	15
Potentilla erecta	5	-	40	15	50
Luzula campestris	30	-	10	-	20
Carex spp.	10	10	10	-	-
Vaccinium myrtillus	10	-	-	-	-
Sieglingia decumbens	5	-	5	15	-
Trifolium repens	15	-	-	-	-
Deschampsia caespitosa ..	20	35	45	5	-

These sites are all found on gentle slopes between 800 and 1,000 feet, where the soils are well aerated and freely drained. Flushing is nowhere intense, but is, nevertheless, present. Agrostis spp. are, in all cases, dominant, Festuca ovina generally being co dominant to sub dominant, though varying from 100% S.F. in Site 8 to 30% in Site 51,/

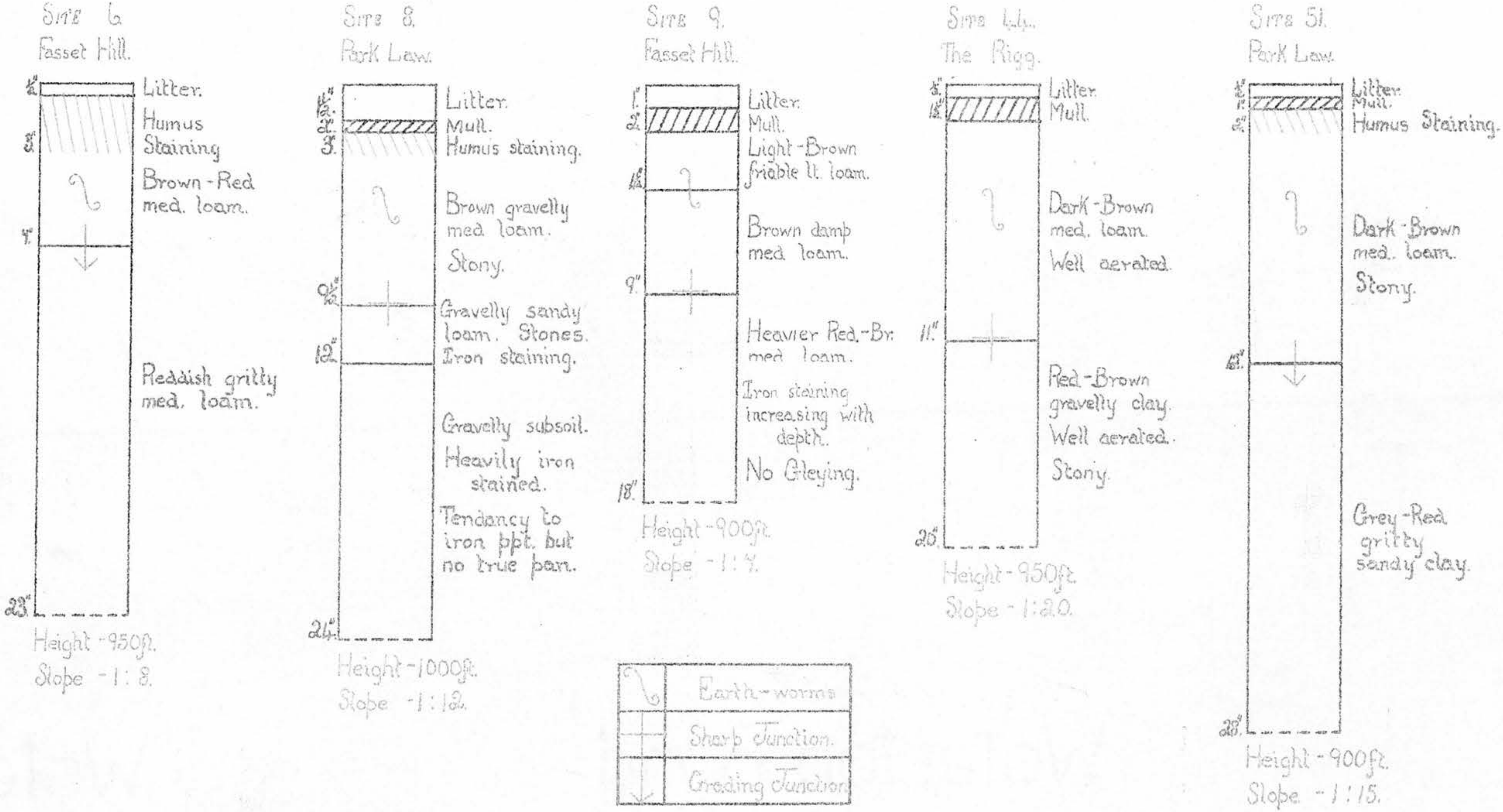
Site 51,. Anthoxanthum odoratum, Poa pratensis, and Galium saxatile are constant species in all the sites, with Deschampsia flexuosa, Holcus mollis, Festuca rubra, Potentilla erecta, and Deschampsia caespitosa in four out of the five. Trifolium repens, wild white clover, was found in one site.

Soil Conditions under Type 1

Soil Profile: In all, fifteen profiles were dug for this type, the five shown diagrammatically on page 108 being composites of three for each site. The soils were all of the Brown-Earth type and contained earthworms in the upper layers.

An undecomposed or litter layer from ½ - 1½ inches thick was present in all the profiles. This graded into a black mull humus horizon from ½ - 1 inch thick. In Site 6 no true humus layer was present, though humus staining was evident in the top three inches of the profile. Humus staining was also observed below the humus layer in Sites 8 and 51. From 6 - 10 inches below the humus layer the soil was a brown to dark-brown, well aerated, medium loam containing many stones and roots. This in turn graded into or showed a sharp junction with a stony, gravelly subsoil of medium-loam to sandy-clay texture. Aeration was good and drainage free except in Site 51, where the clay percentage increased with depth, and there was slight mottling at 26 inches. The colour varied from red-brown to grey-red, and in all /

AGROSTIS I.



Site 6.
Fasset Hill.
Litter.
Humus Staining
Brown-Red med. loam.
Reddish gritty med. loam.
23"
Height - 950ft.
Slope - 1:8.
Site 8.
Park Law.
Litter.
Mull.
Humus staining.
Brown gravelly med. loam.
Stony.
Gravelly sandy loam. Stones. Iron staining.
Gravelly subsoil.
Heavily iron stained.
Tendancy to iron ppt. but no true pan.
24"
Height - 1000ft.
Slope - 1:12.
Site 9.
Fasset Hill.
Litter.
Mull.
Light-Brown friable lt. loam.
Brown damp med. loam.
Heavier Red.-Br. med. loam.
Iron staining increasing with depth.
No Gleying.
18"
Height - 900ft.
Slope - 1:4.
Site 44.
The Rigg.
Litter.
Mull.
Dark-Brown med. loam.
Well aerated.
Red.-Brown gravelly clay.
Well aerated.
Stony.
25"
Height - 950ft.
Slope - 1:20.
Site 51.
Park Law.
Litter.
Mull.
Humus Staining.
Dark-Brown med. loam.
Stony.
Grey-Red gritty sandy clay.
28"
Height - 900ft.
Slope - 1:15.
Earth-worms
Sharp Junction.
Grading Junction

all the profiles some precipitation of iron had been taking place. This was most clearly shown in Sites 8 and 9, the former site showing a tendency to form an iron pan, though no true pan was present.

Loss on Ignition: The humus was all of the black, crumbly mull type. Loss on Ignition figures range in the top-soils from 17.3% in Site 9 to 21.3% in Site 6. The subsoil range is 8.4% in Site 44 to 13.4% in Site 6.

Water/Humus Ratio: For the topsoil samples, the range of Water/Humus is 1.2 in Site 8 to 2.8 in Sites 44 and 51. The subsoils are all generally wetter than the corresponding topsoils apart from Site 44, the range being from 2.1 in Sites 6 and 8 to 4.1 in Site 51. This very high figure in Site 51 may be accounted for by the depth at which the sample was taken (28 inches), where, as has already been mentioned, slight signs of impeded drainage were evident.

pH: The topsoils in this type show a very close similarity in pH, the range being only from 4.8 - 4.9. The subsoils are all less acid than their corresponding topsoils ranging from 5.2 in Site 8 to 5.6 in Site 51.

Exchangeable Calcium: Only Sites 6, 8 and 9 were analysed for exchangeable calcium. The topsoil figures range from 0.054% calcium to 0.089% calcium, and the subsoils from 0.071% to 0.116% calcium. /

calcium. The subsoils are all higher than the topsoils, corresponding with the lower acidity at depth.

Available Phosphates: The topsoil range is small, being from 4.4 mg. per 100 g. in Site 51 to 7.7 mg. in Site 6. The subsoil range is from 4 mg. in Site 9 to 28 mg. in Site 44. The comparison with topsoil figures shows little change in Sites 6, 8 and 9, and an increase in the subsoil in Sites 44 and 51.

Available Potassium: The range in the topsoils is from 0.55 g. in Site 9 to 0.77 g. in Site 51. The subsoils are all lower in potassium than the corresponding topsoils the range being 0.37 g. in Site 44 to 0.53 g. in Site 51.

SUMMARY OF RESULTS

Topsoils:

Site Nos.	- 6, 8, 9, 44 and 51.	
Number of Sites	- 5.	
Number of Samples	- 50.	
Loss on Ignition	- 19.2% (17.3 - 21.3).	
Water/Humus Ratio	- 1.9	(1.2 - 2.8)
pH	- 4.9	(4.8 - 4.9)
Available Phosphates	- 6.5 mgs/100 gms.	(4.4 - 7.7)
Available Potassium	- 0.64 gms.	(0.55 - 0.77)
Exchangeable Calcium	- 0.069% (28 estimations)	(0.054 - 0.089)

Subsoils:

Site Nos.	- 6, 8, 9, 44 and 51.
Number of Sites /	

Number of Sites - 5.

Number of Samples - 15.

Loss on Ignition - 11.1% (8.4 - 13.4)

Water/Humus Ratio - 2.6 (21 - 4.1)

pH - 5.4 (5.2 - 5.6)

Available Phosphates - 11.2 mgms. (4.0 - 28.0)

Available Potassium - 0.47 gms. (0.37 - 0.53)

Exchangeable Calcium - 0.091% (0.071 - 0.116).
(9 estimations)

Type 2:- Sites 39, 40, 45, 48, 50 and 59.

Gleying present.

TABLE 2.

VEGETATION ANALYSIS

	Site					
	39	40	45	48	50	59
Agrostis spp.	80	95	90	20	25	65
Festuca ovina	-	-	55	-	-	-
Deschampsia flexuosa .	5	5	-	-	10	5
Anthoxanthum odoratum	30	10	35	25	15	-
Poa pratensis	30	35	50	10	15	5
Holcus mollis	60	60	30	50	70	40
Festuca rubra	70	30	35	60	65	55
Nardus stricta	30	10	10	-	-	-
Galium saxatile . ..	-	-	-	-	-	5
Potentilla erecta ..	-	-	5	10	10	15
Luzula campestris ..	5	5	30	-	-	-
Carex spp.	15	30	10	30	15	15
Vaccinium myrtillus ..	-	10	-	-	-	-

/

VEGETATION ANALYSIS

	Site					
	39	40	45	48	50	59
Sieglingia decumbens ..	30	5	35	-	-	-
Trifolium repens ..	50	60	35	-	-	10
Juncus communis ..	5	-	-	20	-	25
Deschampsia caespitosa	25	35	60	85	90	50

These sites occur between 800 and 1,100 feet on Sourhope. Site 59 was not on Sourhope and its position is shown on the O.S. Map, page 104. The sites are all subject to more active flushing than those in Type 1, and are found on less acid, wetter soils. Though Type 2 shows a more varied vegetation than Type 1, the soils are all closely comparable and each shows a gley horizon at no great depth below the surface.

Vegetation Analysis:

Agrostis spp in this type share dominance with Deschampsia caespitosa, Festuca ovina being represented only in Site 45. In Sites 48 and 50, Deschampsia caespitosa is dominant, forming large tussocks. Growing within the tussocks, Festuca rubra is abundant. Between the tussocks Holcus mollis, Agrostis spp, Anthoxanthum odoratum, Poa pratensis and Carex spp form the ground vegetation. In Site 45 the S.F. percentage of Deschampsia caespitosa is high, but here it is of a non-tussocky

tussocky type, being a subsidiary sp to Agrostis. It forms part of the sward with Festuca ovina, Anthoxanthum odoratum, Poa pratensis, Holcus mollis, Festuca rubra and Trifolium repens. The position of Site 45 on heavily grazed, sheltered low ground, may account for the non-tufted habit of the Deschampsia caespotisa and the high percentage of Poa pratensis. It should be noticed that this site is the driest of the six in the type. In Site 59, the slope is very gentle (1;20) and sheep graze over it throughout the year. The Deschampsia caespitosa forms small, compact scattered tussocks with Festuca rubra, the ground between the tussocks being dominated by Agrostis spp.. Holcus mollis and Carex spp. In Sites 39 and 40 the Deschampsia caespitosa again forms a few very small tussocks and is more like the type found in Site 45. These two sites are on wet flushes, with a high percentage of Trifolium repens and Holcus mollis, and in Site 39, Festuca rubra.

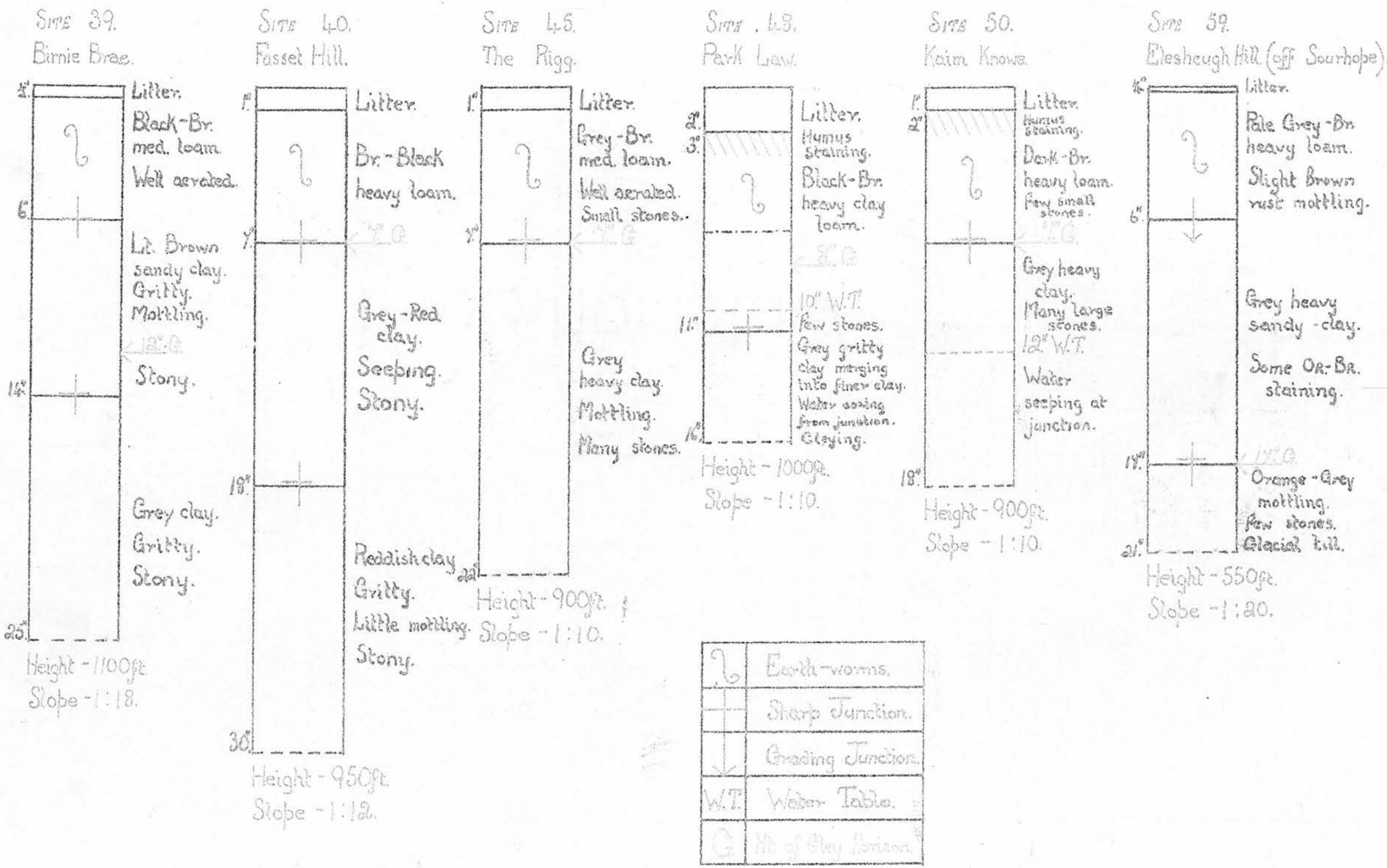
Taking the analysis generally, Agrostis spp, Poa pratensis, Holcus mollis, Festuca rubra, Carex spp. and Deschampsia caespitosa are common to all the sites, and Deschampsia flexuosa, Anthoxanthum odoratum, Nardus stricta,, Potentilla erecta and Trifolium repens are present in four or more.

Soil Conditions under Type 2.

Soil Profile: Eighteen soil profiles were dug and described for this type, the diagrams on page 115 for each site, being a composite of three descr- /

descriptions. The profiles, all showing a gley horizon, are of the Brown-Earth type, showing no signs of podsoilization and containing earthworms in the sub-surface horizons. The litter layer varies from $\frac{1}{2}$ - 2 inches. Unlike Type 1 these profiles have no distinct humus layer immediately below the litter. Sites 50 and 48 show some humus staining in the upper 2 - 3 inches, but this is well mixed with mineral matter and cannot be classed as a true humus layer. The humus present is of a well decomposed mull type and is well distributed through the top 6 - 9 inches of the soil. This gives the soil a darker colour than that found in Type 1, the main colours being from dark-brown to black-brown. The texture is also heavier than that of Type 1, ranging from medium loams through heavy loams to a clay loam in Site 48. The upper horizons contain a few stones and are well aerated with many roots. In Sites 39 and 59, the aerated layer passes through a horizon of gritty, heavy, sandy clay showing a slight mottle before the gley horizon is reached. In the other four sites there is no intermediate layer and the aerated topsoil lies immediately on the gley horizon. The subsoils are all heavy, reddish-grey, gritty clays which normally become finer in texture with depth. Numerous rounded large stones are present in the subsoils, suggesting that the parent material of this type /

AGROSTIS II.


Site 39.
Birnie Brae.
5" Litter.
Black-Br. med. loam. Well aerated.
6"
Lt. Brown sandy clay. Gritty. Mottling.
18" G.
Stony.
14"
Grey clay. Gritty. Stony.
25"
Height - 1100ft.
Slope - 1:18.
Site 40.
Fasset Hill.
1" Litter.
Br.-Black heavy loam.
7"
5" G.
Grey-Red clay. Seeping. Stony.
18"
Reddish clay. Gritty. Little mottling. Stony.
36"
Height - 950ft.
Slope - 1:12.
Site 45.
The Rigg.
1" Litter.
Grey-Br. med. loam. Well aerated. Small stones.
7"
5" G.
Grey heavy clay. Mottling. Many stones.
22"
Height - 900ft.
Slope - 1:10.
Site 48.
Park Law.
2" Litter.
3" Humus staining.
Black-Br. heavy clay loam.
8" G.
10" W.T.
11" Few stones.
Grey gritty clay merging into finer clay. Water oozing from junction. Gleying.
16"
Height - 1000ft.
Slope - 1:10.
Site 50.
Kaim Knowe.
1" Litter.
2" Humus staining.
Dark-Br. heavy loam. Few small stones.
4" G.
Grey heavy clay. Many large stones.
12" W.T.
Water seeping at junction.
18"
Height - 900ft.
Slope - 1:10.
Site 59.
Elesheugh Hill (off Sourhope).
½" Litter.
Pale Grey-Br. heavy loam. Slight Brown rust mottling.
6"
Grey heavy sandy-clay. Some Or.-Br. staining.
17" G.
17"
Orange-Grey mottling. Few stones. Glacial till.
21"
Height - 550ft.
Slope - 1:20.
Earth-worms.
Sharp Junction.
Grading Junction.
W.T. Water Table.
G Ht. of Gley Horizon.

type is a heavy glacial till. In some sites (Site 59) mottling was very intense, showing bright colours of orange and brown, in contrast to the normal grey of the lower horizons.

Loss on Ignition: The topsoils show a much larger variation in Loss on Ignition percentage than in Type 1 - the range being from 10.0% in Site 45 to 36.0% in Site 48. It is of interest to note that the high Loss on Ignition figures of Sites 48 and 50 correspond to the dominance of Deschampsia caespitosa. The subsoils are all low (Site 48 could not be sampled due to oozing water filling the hole), ranging from 6.2% in Site 39 to 8.7% in Site 45. Owing to flooding in Site 50, the subsoil samples were taken at only 10 inches and are thus perhaps not truly representative.

Water/Humus Ratio: This soil type is the wettest of all the non-peaty soils, having a topsoil range of 3.2 in Site 45 to 4.6 in Site 48. The subsoils tend to be slightly wetter than the corresponding topsoils though there is no great increase in any single case, and in Site 39 the subsoil is, if anything, a little drier.

pH: The highest pH results from the seven hundred samples analysed were found in this type. In the topsoils, the pH ranged from 5.0 in Site 48 to 5.7 in Site 40, being highest in Sites 39 and 40, where active flushing was taking place. The subsoils are all less acid than the topsoils, /

topsoils, ranging from 5.4 in Site 50 to 6.1 in Site 45. This latter figure is the highest mean pH found in any site on the farm.

Exchangeable Calcium: Sites 39, 40 and 50 were estimated for exchangeable calcium. The topsoil range, from 0.079% in Site 39 to 0.155% in site 40 is the highest of all the vegetation types investigated. The subsoil range is also high (0.057 in Site 39 to 0.103 in Site 40) though the results show that the subsoils are lower than their corresponding topsoils.

Available Phosphates: Phosphates are all very low, the topsoil range being only 3.0 mg. per 100 g. in Sites 39, 40 and 45 to 6.2 mg. in Site 48. The subsoils are all similar to the topsoil figures or higher, the range being from 4.0 mg. in Sites 39 and 40 to 17.0 mg. in Site 59.

Available Potassium: This type shows a high amount of available potassium in the topsoils - range 0.52 g. in Site 39 to 0.78 g. in Site 48 - and is rated as "High" to "Very High" by arable standards. The subsoils are lower, ranging from 0.37 g. in Site 45 to 0.44 g. in Site 40.

SUMMARY OF RESULTS

Topsoils:

Site Nos. - 39, 40, 45, 48, 50 and 59.

Number of Sites - 6.

Number of Samples - 60.

Loss on Ignition /

Loss on Ignition	- 20.4%	(10.0 - 36.0)
Water/Humus Ratio	- 3.9	(3.2 - 4.6)
pH	- 5.4	(5.0 - 5.7)
Available Phosphates	- 4.0 mgms.	(3.0 - 6.2)
Available Potassium	- 0.61 gms.	(0.52 - 0.78)
Exchangeable Calcium	- 0.111% (30 estimations)	(0.079 - 0.155)

<u>Subsoils</u>:

Site Nos.	- 39, 40, 45, 50 and 59.	
Number of Sites	- 5.	
Number of Samples	- 15.	
Loss on Ignition	- 8.8%	(6.2 - 15.2)
Water/Humus Ratio	- 3.9	(3.0 - 4.6)
pH	- 5.8	(5.4 - 6.1)
Available Phosphates	- 7.2 mgms.	(4.0 - 17.0)
Available Potassium	- 0.41 g.	(0.37 - 0.46)
Exchangeable Calcium	- 0.081%	(0.057 - 0.103)

The Distribution of Deschampsia caespitosa in the Agrostis-fescue Type related to W/H and the Height of the Gley Horizon.

Table 3.

Site No.	% Dc	W/H	No Gleying	Gleying	Depth of Gley Horizon.
6	20	1.32	+		
8	35	1.23	+		
9	45	1.51	+		
39	25	3.97		+	12"
40	35	3.49		+	8"
44	5	2.78	+		
45	60	3.17		+	8"
48	85	4.55		+	6"
50	90	4.04		+	8"
51	0	2.84		+	20" (slight)
59	50	4.15		+	17"

From the above Table No. 3, the distribution of Deschampsia caespitosa can be seen in relation to W/H and the presence or absence of gleying. Because of what has already been said concerning the error in the method of vegetation analysis (see Page 96), when dealing with ~~spp~~ species of low frequency, no attempt will be made to compare small differences of percentage frequencies with changes in water content. The overall picture has, however, some interesting points with reference to the occurrence of this ~~sp~~ species on Sourhope Farm.

In the two sites, no's 34 and 51, where ~~Dc~~ Deschampsia caespitosa did not occur, no gleying was observed in the profile apart from a slight mottle at depth in No. 51.

In sites 6, 8, 9, 29, and 44, ~~Dc~~ Deschampsia caespitosa was present in relatively small amounts (5 - 45%- and the W/H factor had a mean of 1.90 (range 1.3 - 2.8). No gleying was apparent in any of these profiles.

In sites 30, 40, 45, 48, 50, and 59, a gley horizon was present, the depth from the soil surface being indicated in the Table. The percentage of Deschampsia caespitosa ranges from 25 - 90% and the mean of the W/H rates is 3.9 with a range of 3.2 - 4.6.

Comparable W/H subsoil figures for the non-gleyed types are 2.2 (Range 2.1 - 2.3) and for the gleyed (3.0 - 4.6). In site 29, the subsoil was composed of rock rubble and was not sampled, and in site 48, seeping water prevented sampling.

It is thus apparent that on Sourhope, Deschampsia caespitosa is found in greatest abundance where the soils are wet and have a gley horizon at no great depth below the surface.

Table 4.

	Mean % Dc	Mean Topsoil W/H	Mean Subsoil.
Non gleyed type	22	1.9	2.2
Gleyed type	58	3.9	3.9

CALLUNA VULGARIS TYPE

This vegetation type is very poorly represented on Sourhope Farm and for this reason the areas sampled were not on the farm, with the exception of Site 61. The figures and analyses were obtained from Calroost and Kelso Cleugh (Bowmont), Heatherhope (in the headwaters of the Kale Water) and from sites at the head of the College Valley, on the English side of the Border in the foothills of the Cheviot. These areas are indicated on the O.S. Map, page 104. It was considered that Calluna Vulgaris covers such large areas in the Cheviot Hills, that it should be included in the main vegetation types investigated in the course of this work. (See Photos 10 and 11).

Two main types of Calluna sites have been distinguished, depending on soil profile: Type 1 - Calluna dominant on peat over 8 inches in depth, and Type 2 - Calluna dominant on "peat" under 8 inches. These two types will be described separately.

Type 1 -

Calluna on Peat over 8 inches in Thickness

Sites 47, 56, 57 and 61

The sites from which the data ~~was~~ were obtained ~~were~~ are situated between 1,100 - 1,600 feet, on land which was flat or gently sloping. The organic layer ~~was~~ is a true peat, having been formed /

Photo. 10. (Heatherhope)

This shows the type of country at the source of the Kale Water where some of the Calluna sites used in this thesis are situated. The heather occurs in patches on the hillsides — no single area covering a very large acreage. See also Photo. 8.

Photo. 11. (College Valley)

Here the heather is much more widespread than at Heatherhope. The peat is cut for fuel, the workings being visible in the right foreground of the photograph.

formed under very wet reducing conditions. Sites 47, 56 and 61 are climatic peats, and Site 51, by virtue of its position on the valley floor, is of the Basin peat type.

TABLE 5.

VEGETATION ANALYSIS

Percentage of Specific Frequency

Species	Site 47	Site 56	Site 57	Site 61
Calluna vulgaris	100	100	100	100
Deschampsia flexuosa . ..	30	-	-	-
Vaccinium myrtillus	20	-	5	5
Potentilla erecta	-	5	-	-
Nardus stricta	-	45	-	-
Agrostis spp.	-	10	-	-
Molinia caerulea	-	15	-	-
Eriophorum vaginatum . ..	-	-	80	80
Scirpus caespitosus	-	20	30	-
Juncus squarrosus	30	-	-	-
Erica tetralix	-	40	40	20
Empetrum nigrum	-	-	-	45

Calluna vulgaris is in all the cases dominant and the only species present in all of the four analyses. In Sites 57 and 61, i.e. on the very deep peats, Eriophorum vaginatum is sub-dominant. Whether this species was at one time dominant and is now being ousted by Calluna, is not known. Leaf bases found at 18 inches in Site 61 were /

Photo. 12. (Site 47)

Calluna vulgaris with patches of Juncus squarrosus.

were thought to be those of Eriophorum. The great depth of the peat in these two sites, however, suggests that further study would show a succession from Sphagnum peat, through Eriophorum types to Calluna peat. It is of interest to note that tree roots were found at 30 inches in Site 57, though no forest remains were found in Site 61. In Site 47, which is the driest site in this group, small amounts of Deschampsia flexuosa and Vaccinium myrtillus occur. Juncus squarrosus is also present, forming small patches among the heather. See Photograph No. 12 . Nardus stricta is present in appreciable quantity in Site 56. Whether this is due to burning is not known. Site 56, however, is the only site of the ten investigated which contains Nardus. On the wetter areas, Sites 56 and 57, Scirpus caespitosus, Molinia caerulea, and Erica tetralix are common, and on the very wet Site 61, Empetrum nigrum is frequent. Agrostis spp. and Potentilla erecta are present in Site 56, but are not characteristic of the type.

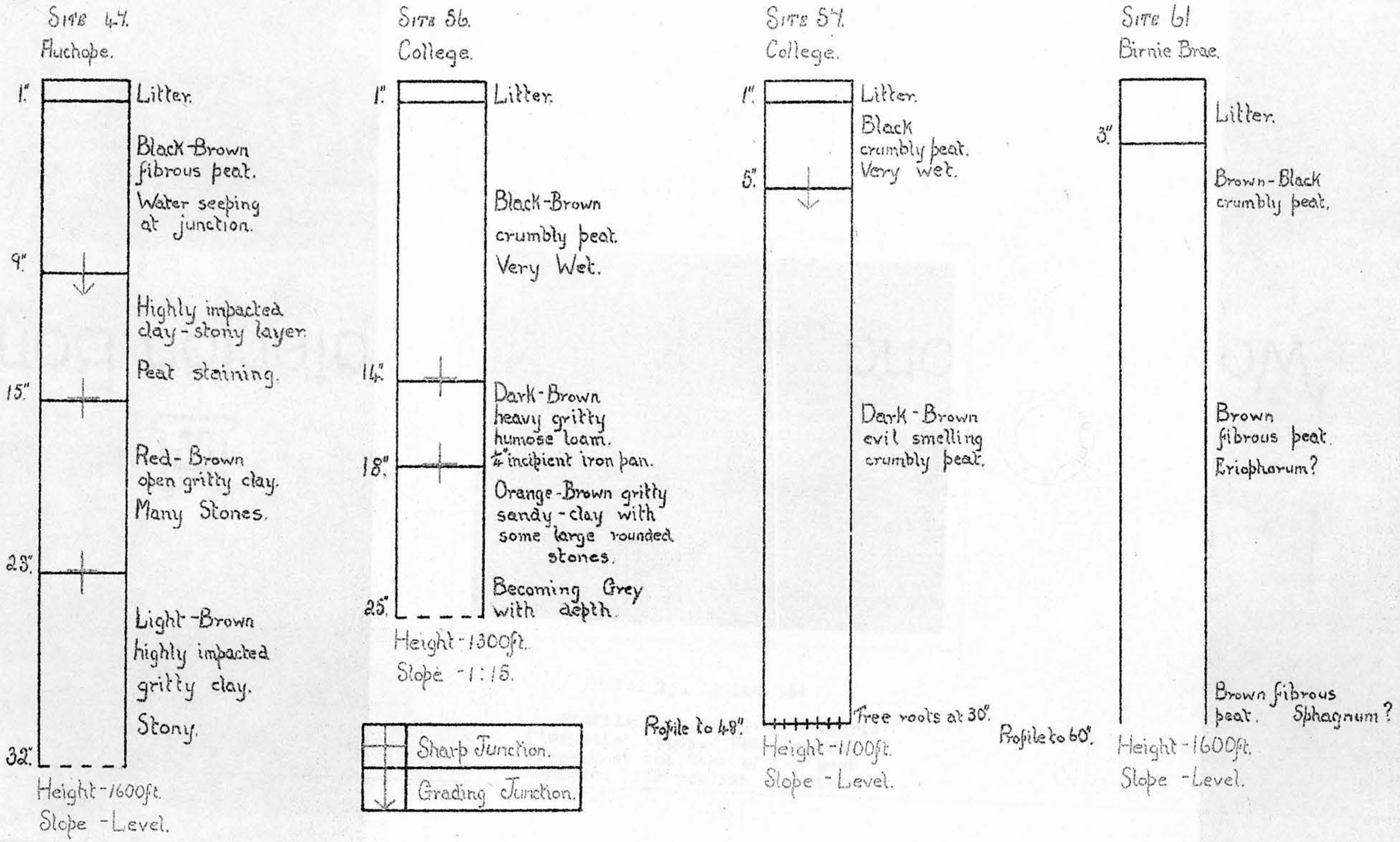
Soil Conditions under Calluna Type 1

Soil Profiles: In Sites 57 and 61, the peat was so deep that the mineral soil was not reached in the profile. It is estimated that the peat in both sites was at least 7 - 8 feet thick. In the uppermost layer of both these sites, the peat was much blacker and more crumbly than the /

the dark-brown peat found below. This blacker layer 4 - 6 inches thick below the surface litter may be due, either to more aerated conditions near the surface of the peat, or to the fact that it has been formed by a different species of plant than that which formed the peat below. The writer suggests that, as the peat below is brown and very fibrous and that above is crumbly and black, they are of different origins, and that Calluna has ousted an Eriophorum type of vegetation due to drying of the surface layers of the peat. In Sites 47 and 56 the peat is 9 - 14 inches deep (See Photo No. 13). Both the peats rest on an impervious sub-peat layer causing water to seep from the peat - mineral soil junction. In Site 56 this impervious layer is formed by 4 inches of heavy, dark brown, humose loam, with an incipient iron pan ¼ inch thick at 18 inches. Below the iron pan the subsoil is an orange-brown, gritty sandy-clay containing large rounded stones. The subsoil becomes greyer with depth. In Site 47 the drainage is impeded by 6 inches of highly impacted, grey-brown, stony clay immediately below the peat. This horizon shows a sharp transition at 15 inches to a free-draining, red-brown, gritty clay with many stones. The subsoil is composed of a light-brown, highly compacted, gritty clay.

Loss on Ignition: /

CALLUNA I.



Site 47.
Auchope.
1"
Litter.
Black-Brown fibrous peat.
Water seeping at junction.
9"
Highly impacted clay-stony layer.
Peat staining.
15"
Red-Brown open gritty clay.
Many Stones.
23"
Light-Brown highly impacted gritty clay.
Stony.
32"
Height-1600ft.
Slope -Level.
Site 56.
College.
1"
Litter.
Black-Brown crumbly peat. Very Wet.
14"
Dark-Brown heavy gritty humose loam.
¼" incipient iron pan.
18"
Orange-Brown gritty sandy-clay with some large rounded stones.
Becoming Grey with depth.
25"
Height-1300ft.
Slope -1:15.
Sharp Junction.
Grading Junction.
Site 57.
College.
1"
Litter.
Black crumbly peat. Very wet.
5"
Dark-Brown evil smelling crumbly peat.
Tree roots at 30".
Profile to 48".
Height-1100ft.
Slope -Level.
Site 61
Birnie Brae.
3"
Litter.
Brown-Black crumbly peat.
Brown fibrous peat. Eriophorum?
Brown fibrous peat. Sphagnum?
Profile to 60".
Height-1600ft.
Slope -Level.

Photo. 13. (Site 56)

Profile under Calluna vulgaris ("organic" type). Note lateral seepage at the base of the peat horizon. For profile description see page 127.

<u>Loss on Ignition</u>: The Loss on Ignition figures are very high for this type, ranging in the topsoils from 80.7% in Site 47 to 97.1% in Site 61. In the deep peat type only one profile was dug per site, three subsoil samples being taken at various depths. The peat analysis figures are given at the end of this section. In Sites 47 and 56, (three profiles in each), the Loss on Ignition percentage ranged from 10.8 to 17.4%

<u>Water/Humus Ratio</u>: The peats in this type are all very wet, ranging in the topsoils from 3.51 in Site 47 to 6.61 in Site 61. In the subsoils the deep peat type is wetter - 5.59 in Site 57 and 9.20 in Site 61 - than its corresponding topsoil while the mineral subsoil below the shallower peat is a little drier (3.43 in Site 47 and 3.80 in Site 56).

<u>pH</u>: The topsoil peats are very acid, ranging from 3.6 in Site 57 to 3.9 in Site 61. The peat subsoils show little change in acidity from the topsoil figures, though the mineral soil subsoils are much less acid than their corresponding topsoils, the pH in each case being 4.9.

<u>Available Phosphates</u>: Phosphates are very low throughout the type, the topsoil range being from 3.1 mg. per 100 g. in Site 61 to 6.1 mg. in Site 47. The subsoils are all between 3 and 4 mg.

<u>Available Potassium</u>: /

Available Potassium: Potassium is very high in the topsoils, ranging from 0.8 g. in Site 57 to 1.10 g. in Site 61. It should be borne in mind that by arable standards, over 0.75 g. is rated "very high". The peat subsoils are also high in potassium, though a little lower than the topsoils; the mineral subsoils are very much lower.

SUMMARY OF RESULTS

Topsoils:

Site Nos.	- 47, 56, 57, and 61.	
Number of Sites	- 4.	
Number of Samples	- 40.	
Loss on Ignition	- 91.6%	(80.7 - 97.1).
Water/Humus Ratio	- 4.68	(3.51 - 6.61).
pH	- 3.8	(3.6 - 3.9).
Available Phosphates	- 4.1 mgms/100 gms	(3.1 - 6.1).
Available Potassium	- 0.92 gms.	(0.80 - 1.10).
Exchangeable Calcium	- 0.044% (13 estimations)	(0.033 - 0.054)

Subsoils - Mineral Soil:

Site	n	L.I.	W/H	pH	P_2O_5	K_2O	Ex.Ca.%
47	3	10.8	3.43	4.9	3.0	0.33	0.002
56	3	17.4	3.80	4.9	4.0	0.45	-

Subsoils - Peat:

Site	Depth ins	L.I.%	W/H	pH	P_2O_5	K_2O	Ex. Ca.
57	14	96.8	5.16	3.6	3.0	0.68	
	23	97.4	5.34	3.8	3.0	0.55	
	32	97.8	6.26	3.7	3.0	0.50	
Mean:		97.3	5.59	3.7	3.0	0.58	0.041

Site	Depth ins	L.I.%	W/H	pH	P_2O_5	K_2O	Ex. Ca.%
61	15	97.2	8.30	3.9	3.0	0.97	-
	30	98.7	10.35	3.9	3.0	0.61	-
	60	98.3	8.95	3.7	3.0	1.12	-
Mean:-		98.1	9.20	3.8	3.0	0.90	-

Type 2 -

Calluna on Peat less than 8 Inches thick

Sites 52, 53, 54, 55, 58 and 60

This type of Callunetum, growing on a very thin organic layer, was found on steeper slopes than Type 1, the steepest being approximately 1:4, and the most gentle 1:15. These sites are situated on the upper and lower slopes of the hills at heights between 700 and 1,400 feet. As already discussed in the section under soils (page 76.), the organic layer should be termed "mor humus" rather than peat, the conditions of formation being aerobic.

TABLE 6.

VEGETATION ANALYSIS

Percentage of Specific Frequency

Species	Site					
	52	53	54	55	58	60
Calluna vulgaris ..	100	100	100	100	100	100
Deschampsia flexuosa .	5	5	-	45	75	10
Vaccinium myrtillus ..	5	5	-	45	75	10
Agrostis spp.	-	-	-	5	-	-
Festuca ovina /						

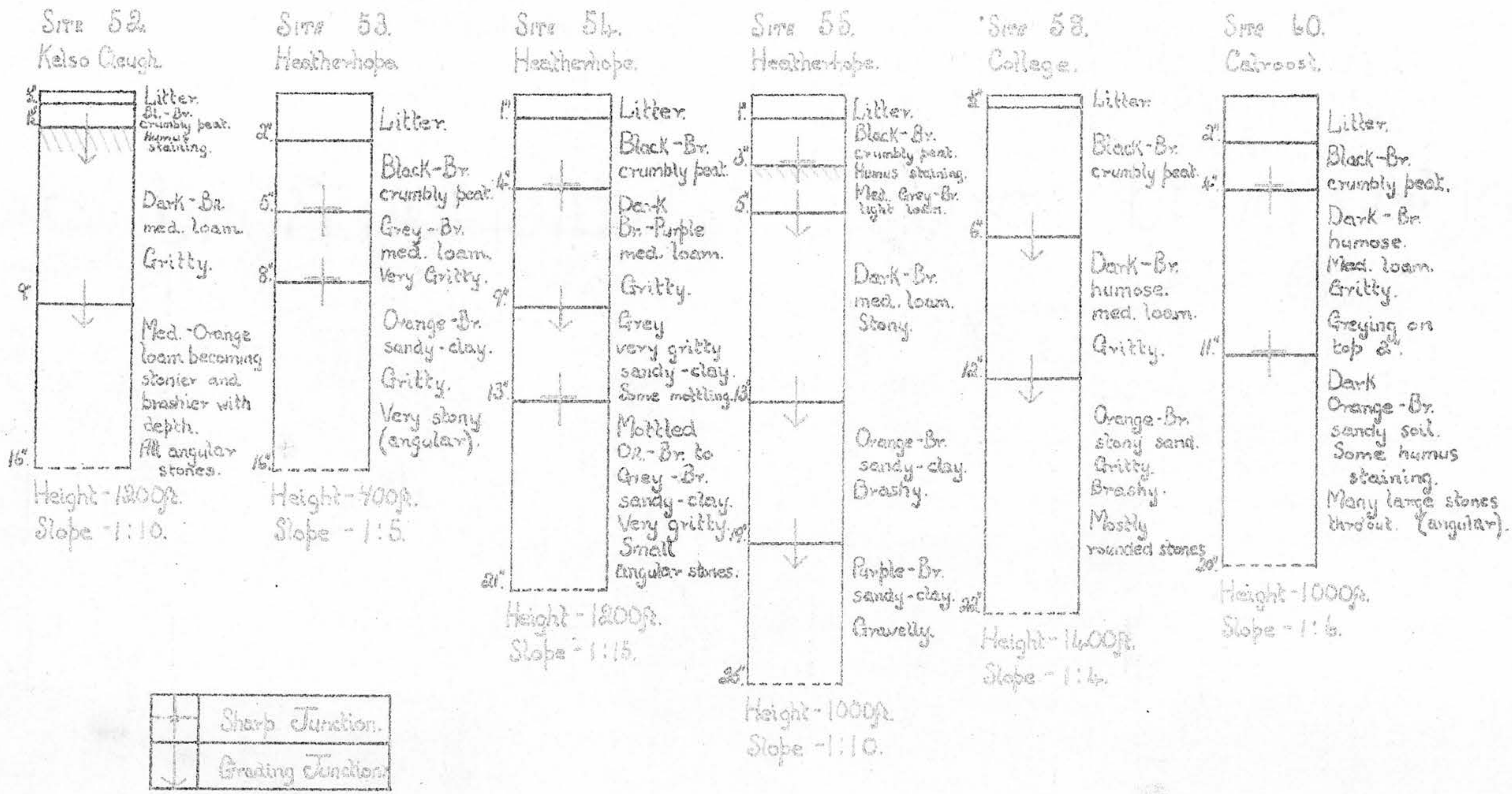
Species	Site					
	52	53	54	55	58	60
Festuca ovina	15	-	-	-	-	-
Luzula sylvatica . ..	5	-	-	-	-	-
Pteridium aquilinum...	-	-	-	-	5	-

This drier type of Callunetum is floristically very poor, seven species being represented in the six analyses. Of these, only two, apart from Calluna vulgaris, play any significant role. These are Deschampsia flexuosa and Vaccinium myrtillus. In Site 54, Calluna was exclusive, no other species being present apart from moss. Mosses are not included in the Specific Frequency figures. In Site 58, the Vaccinium is very short and nowhere attains even local dominance. The Calluna on this site is regularly burned. In Site 55, appreciable amounts of Deschampsia flexuosa and Vaccinium occur, but in Sites 52, 53 and 60, subsidiary species are so few and of such low frequency that the Calluna could almost be termed "exclusive".

<u>Soil Conditions under Calluna - Type 2</u>

<u>Soil Profile</u>: The litter layer varies from ½ inch to 2 inches. This grades into a layer of raw mor humus, which, in the sites examined, reached a maximum thickness in Site 58 of 6 inches and a minimum in Site 52 of 1 inch. The mor humus /

CALLUNA II.



Site 52.
Kelso Cleugh.
Litter.
Bl.-Br. crumbly peat.
Humus staining.
Dark-Br. med. loam.
Gritty.
Med.-Orange loam becoming stonier and brashier with depth.
All angular stones.
Height - 1200ft.
Slope - 1:10.
Site 53.
Heatherhope.
Litter.
Black-Br. crumbly peat.
Grey-Br. med. loam. Very Gritty.
Orange-Br. sandy-clay.
Gritty.
Very stony (angular).
Height - 400ft.
Slope - 1:5.
Site 54.
Heatherhope.
Litter.
Black-Br. crumbly peat.
Dark Br.-Purple med. loam.
Gritty.
Grey very gritty sandy-clay.
Some mottling.
Mottled Or.-Br. to Grey-Br. sandy-clay.
Very gritty.
Small angular stones.
Height - 1200ft.
Slope - 1:15.
Site 55.
Heatherhope.
Litter.
Black-Br. crumbly peat.
Humus staining.
Med. Grey-Br. light loam.
Dark-Br. med. loam.
Stony.
Orange-Br. sandy-clay.
Brashy.
Purple-Br. sandy-clay.
Gravelly.
Height - 1000ft.
Slope - 1:10.
Site 58.
College.
Litter.
Black-Br. crumbly peat.
Dark-Br. humose. med. loam.
Gritty.
Orange-Br. stony sand.
Gritty.
Brashy.
Mostly rounded stones.
Height - 1400ft.
Slope - 1:4.
Site 60.
Cairoost.
Litter.
Black-Br. crumbly peat.
Dark-Br. humose. Med. loam.
Gritty.
Greying on top 2".
Dark Orange-Br. sandy soil.
Some humus staining.
Many large stones thro'out. (angular).
Height - 1000ft.
Slope - 1:6.
Sharp Junction.
Grading Junction.

Photo. 14. (Site 53)

Profile under Calluna vulgaris ("mineral" type). For profile description see page 133.

humus is in every case brown-black in colour, and crumbly, containing many fine roots. The mor layer grades or shows a sharp transition into a gritty, dark-brown to grey-brown, medium loam, 2 to 8 inches thick. This horizon is normally humus stained in the top few inches. In Site 60, immediately below the humus layer, is a greyer horizon 2 inches thick. It is probably the primitive A_2 horizon of a podsol. A similar, but better developed, grey horizon is shown in Site 55. In Sites 52, 53, (See Photo. No. 14) 58 and 60 the gritty, medium loam passes directly into a medium - orange to orange-brown subsoil of varying texture. These subsoils are all very stony, and, in many cases, brashy. The stones are angular in Sites 52, 53 and 60, and are mixed angular and rounded in Site 58. In Site 54, the sub-humus, gritty, medium loam passes into a grey, very gritty, sandy clay which shows some mottling. This, in turn, rests on a mottled, orange-brown, sandy-clay sub-soil containing small angular stones. In Site 55, the profile grades from the dark-brown medium loam through 6 inches of brashy, orange-brown, sandy-clay to a purple-brown, gravelly, sandy clay.

<u>Loss on Ignition:</u> In this type of Callunetum, the organic matter contains a much higher percentage of mineral matter than that found in Type 1. At the same time, it should be remembered that the topsoil samples were taken to 5 inches, so that /

that part of the mineral, sub-peat layer will be included in the analysis. The topsoils range from 25.2% in Site 52 to 50.6% in Site 58. The sub-soils are all much lower, giving results from 6.3% in Site 54 to 19.4% in Site 60.

Water/Humus Ratio: Although much drier than the deep peat type of Callunetum, the soils are still generally wet, having a topsoil range of Water/-Humus from 2.70 in Site 55 to 3.58 in Site 58. The subsoils show no constant relationship to the corresponding topsoils, in some cases (Sites 52, 58 and 60) being drier, and in others (Sites 53, 54 and 55), wetter. The subsoils which are wetter are those of the heavier, sandy clay texture.

pH: The topsoil range of acidity is from 3.7 in Site 54 to 4.1 in Site 52. It is thus slightly less acid than the deep peat type. The subsoils are again much less acid than the topsoils, the range being from 4.8 in Site 54 to 5.1 in Site 55. In this, they closely resemble the mineral soil under the deeper peats.

Available Phosphates: The topsoil range for phosphates is higher than that for the deep peats, being from 3.5 mg. per 100 g. in Site 58 to 10.9 mg. in Site 52. The subsoils of this type of Callunetum are remarkably high in available phos-phates, ranging from 13.0 mg. per 100 g. in Site 53 to 62.0 mg. in Site 54. A result of over 26.0 mg. per 100 g. is rated "very high" by arable /

arable standards. The subsoil samples from which these mean phosphate figures are obtained, were all re-checked, and gave closely comparable results.

Available Potassium: The potash range of the topsoils is again high and shows little variation between sites - 0.73 g. in Site 52 to 0.81 g. in Site 60. The subsoils are all lower, the range being from 0.36 g. in Site 58 to 0.59 g. in Site 53.

SUMMARY OF RESULTS

Topsoils:

Site Nos.	- 52, 53, 54, 55, 58 and 60.	
Number of Sites	- 6.	
Number of Samples	- 60.	
Loss on Ignition	- 36.8%	(25.2 - 50.6).
Water/Humus Ratio	- 3.00	(2.70 - 3.53).
pH	- 3.9	(3.7 - 4.1).
Available Phosphates	- 6.9 mgms/100 gms	(3.5 - 10.9).
Available Potassium	- 0.77 gms	(0.73 - 0.81).
Exchangeable Calcium	- 0.023% (20 estimations)	(0.012 - 0.039).

Subsoils:

Site Nos.	- 52, 53, 54, 55, and 58, 60.	
Number of Sites	- 5.	
Number of Samples	- 15.	
Loss on Ignition	- 11.9%	(6.3 - 19.4).
Water/Humus Ratio	- 3.2	(2.43 - 4.16).
pH	- 4.9	(4.7 - 5.1).
Available Phosphates	- 28.5 mgms/100 gms	(13.0 - 62.0).
Available Potassium	- 0.50 gms	(0.36 - 0.59).
Exchangeable Calcium	- 0.004% (4 estimations).	(0.003 - 0.005)

NARDUS STRICTA TYPE

The Moor Mat grass, Nardus stricta, is found at all altitudes and is present, to some extent, in almost all the vegetation types on Sourhope Farm. It tolerates a wide range of soil conditions, but is most common where the soils are acid with a sub-surface raw humus or peat horizon. Despite its widespread distribution, this species does not dominate large areas, usually occurring in the sub-dominant to frequent category. In the course of selecting sites for investigation, Nardus was treated by the writer as an indicator of changing or transitional conditions in a plant association. For this reason, where possible, plant associations of the other four types examined which contained a high percentage of Nardus, were excluded. In the areas where Nardus was dominant, two main sub-types were distinguished with reference to soil profile. In the first sub-type, the sub-litter horizon is a raw humus band, ½ to 1½ inches thick; in the second, the Nardus grows on "peat", 4 to 20 inches thick.

Sub-Type 1 - Nardus - thin raw humus horizon
Sites 13, 19, 20, 22, 36, 38 and 63

This type of Nardus vegetation is found on the lower, more gentle hill slopes, between 700 and 1,050 feet and with a slope between 1:6 and 1:20. The soils are leached and free-draining.

TABLE I

VEGETATION ANALYSIS

Percentage of Specific Frequency

Species	Site						
	13	19	20	22	36	38	63
Nardus stricta	95	100	85	100	100	85	85
Agrostis spp.	45	75	55	65	85	75	60
Deschampsia flexuosa . ..	60	95	80	70	55	20	55
Festuca ovina	10	20	45	45	20	-	20
Galium saxatile	65	35	35	55	30	5	20
Potentilla erecta	70	50	40	75	-	25	45
Luzula campestris	35	55	5	10	-	25	5
Poa pratensis	-	-	-	-	-	5	-
Carex spp.	-	5	5	-	-	-	-
Vaccinium myrtillus	-	20	10	-	-	-	25
Anthoxanthum odoratum ..	25	5	20	55	25	40	10
Holcus mollis	-	-	-	-	5	65	-
Festuca rubra	5	-	-	-	10	60	15
Luzula sylvatica	-	-	25	5	-	-	-
Sieglingia decumbens	5	-	-	-	-	5	-
Lathyrus montanus	-	-	5	-	-	10	5
Deschampsia caespitosa ..	-	-	-	-	-	15	-
Trifolium repens	-	-	-	-	-	20	-

Nardus stricta is in all cases dominant, with Agrosostis spp., Deschampsia flexuosa, Galium saxatile and Anthoxanthum odoratum present in all seven sites. The percentage of Agrostis and Deschampsia /

Photo. 15. (Site 58)

Nardus stricta - Agrostis spp. community. This is a typical "rough" Agrostis type probably due to the heavy grazing throughout the year.

Deschampsia flexuosa is high, these species being common sub-dominants. The analysis for Site 38 is of interest when compared with those of the other six sites. The profile and soil analysis results indicate that this association, though dominated by Nardus, is of a much better type, more akin to the wetter Agrostis-fescue community already described (see page 111). This is borne out by the subsidiary species. The presence of Trifolium repens, Deschampsia caespitosa and Poa pratensis indicates a higher level of soil fertility, a fact confirmed by the very low percentage of Galium saxatile and Deschampsia flexuosa.

Festuca ovina, Potentilla erecta and Luzula campestris are found in six out of the seven sites, and Vaccinium myrtillus, Holcus mollis (note particularly Site 38), Festuca rubra (N.B. Site 38), Lathyrus montanus and Luzula sylvatica are common associates. Luzula sylvatica, considered by some to be a woodland relict, is found in widely scattered patches on Sourhope.

Soil Conditions under Nardus Sub-Type 1

Soil Profile:

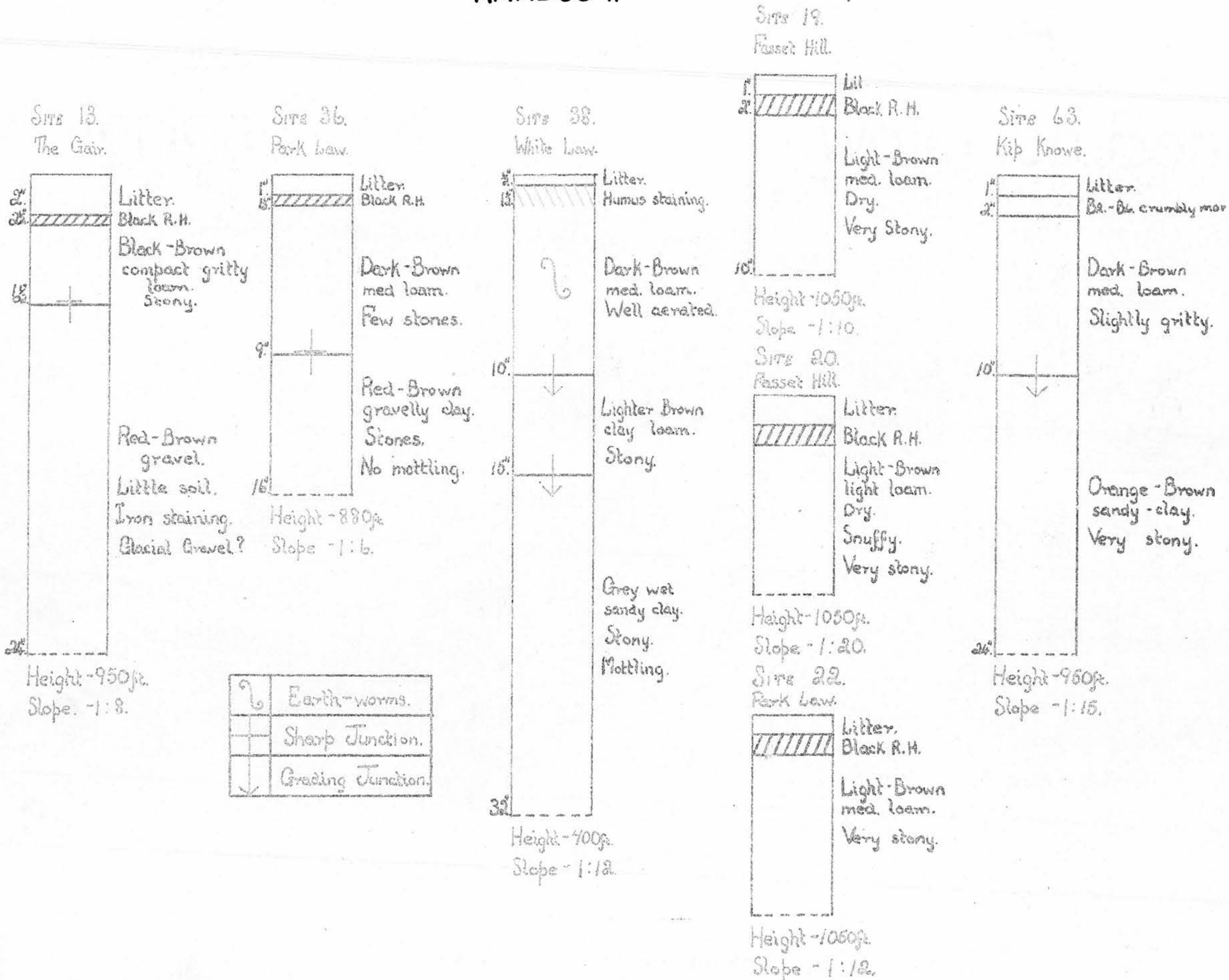
In this type eleven complete profiles were taken in Sites 13, 36, 38 and 63. These are shown as a composite diagram for each site on page 143. In sites 19, 20 and 22, lack of time prevented complete profiles from being taken. The top 10 inches of each were exposed, however, and /

and the data ~~is~~ are given on page 143. The presence of the thin, sub-litter humus layer in each permitted their inclusion in this sub-type.

A well defined litter horizon from $\frac{1}{2}$ to 2 inches thick is present in all seven profiles. This grades in all the sites, with the exception of Site 38, into a fibrous, black, mor humus layer from $\frac{1}{2}$ to 1 inch thick. In Site 38, the top 2 inches of the mineral horizon are humus stained, though no true humus layer is present. The soil below the humus layer varies from light-brown to black-brown in colour. The texture is a light to medium loam. Angular or round stones are normally present, and the horizon is free-draining and well aerated. Earthworms were only found in Site 38. This horizon is from 4 to 8 inches thick.

In Sites 13, 36 and 63, the sub-humus horizon passes immediately into the subsoil. This varies in texture from an almost pure gravel in Site 13 to a gravelly or sandy clay in Sites 36 and 63. The subsoil colour is red or orange-brown, and iron staining is common. The subsoils are all free-draining with no indications of drainage impedance. In Site 38, the profile shows below the dark-brown topsoil a light-brown, stony, clay-loam horizon. This grades into the true subsoil, which is a grey, wet, sandy clay, with many large rounded stones. This horizon shows some mottling./

NARDUS I.



Site 13.
The Gair.
2"
2½"
Litter.
Black R.H.
Black-Brown
compact gritty
loam.
Stony.
Red-Brown
gravel.
Little soil.
Iron staining.
Glacial Gravel?
24"
Height-950ft.
Slope. -1:8.
Site 36.
Park Law.
1"
1½"
Litter.
Black R.H.
Dark-Brown
med loam.
Few stones.
9"
Red-Brown
gravelly clay.
Stones.
No mottling.
16"
Height-880ft.
Slope -1:6.
Site 38.
White Law.
Litter.
Humus staining.
Dark-Brown
med. loam.
Well aerated.
10"
Lighter Brown
clay loam.
Stony.
15"
Grey wet
sandy clay.
Stony.
Mottling.
32"
Height-900ft.
Slope -1:12.
Site 19.
Fasset Hill.
1"
2"
Lit
Black R.H.
Light-Brown
med. loam.
Dry.
Very Stony.
10"
Height-1050ft.
Slope -1:10.
Site 20.
Fasset Hill.
Litter.
Black R.H.
Light-Brown
light loam.
Dry.
Snuffy.
Very stony.
Height-1050ft.
Slope -1:20.
Site 22.
Park Law.
Litter.
Black R.H.
Light-Brown
med. loam.
Very stony.
Height-1060ft.
Slope -1:12.
Site 63.
Kip Knowe.
1"
2"
Litter.
Br.-Bl. crumbly mor
Dark-Brown
med. loam.
Slightly gritty.
10"
Orange-Brown
sandy-clay.
Very stony.
24"
Height-960ft.
Slope -1:15.
Earth-worms.
Sharp Junction.
Grading Junction.

mottling.

It may be mentioned at this juncture that, by virtue of its profile and soil characteristics, Site 38 should have been more correctly grouped with the gleyed type of Agrostis-fescue community. The vegetation is, however, dominantly Nardus stricta, and as the sites were selected on a vegetational basis, it must therefore be included in this type. The analysis figures will therefore be given separately at the end of this section, and not included in the general discussion of this type.

Loss on Ignition:

The topsoil figures vary from 19.5% in Site 36 to 29.6% in Site 22. The subsoils are all lower, showing a range from 11.6% in Site 36 to 15.7% in Site 13.

Water/Humus Ratio:

These soils are relatively dry, the topsoil results showing a Water/Humus range from1.18 in Site 13 to 2.74 in Site 63. The subsoils vary from 1.57 in Site 13 to 2.36 in Site 63. They are thus drier, or only slightly wetter than their corresponding topsoils.

pH:

When compared with the other vegetation types examined, the soils are not very acid, ranging from pH 4.4 in Site 63 to 5.1 in Site 36. The subsoils are all less acid than the topsoils, /

topsoils, varying from pH 4.8 in Site 63 to 5.3 in Site 36.

Exchangeable Calcium:

The topsoils are relatively very low in exchangeable calcium. Of the five sites for which estimations were made, the lowest was 0.024% calcium in Site 13 and the highest 0.035 in Site 20. Two subsoils' results are available - Site 13 - 0.018% Calcium, and Site 36 - 0.032% calcium.

Available Phosphates:

The topsoil range of available phosphates, from 4.1 mg. per 100 g. in Site 63 to 13.0 mg. in Site 13, is a relatively low one. The subsoils, however, have the very high results of from 20 mg. per 100 g. in Site 36 to 48 mg. in Site 13. This is very similar to the phosphate status of topsoils and subsoils under the thin mor layer type of Calluna.

Available Potassium:

The trend shown by many of the soils analysed, of high potassium in the topsoils and low potassium in the subsoils, is carried on in this type. The topsoil range is from 0.43 g. in Site 13 to 0.85 g. in Site 63, while the corresponding subsoil is always lower, varying from 0.24 g. in Site 13 to 0.66 g. in Site 63.

Summary of Results for Nardus Sub-Type 1

Topsoils:

Site Nos.	-	13, 19, 20, 22, 36 and 63.	
Number of Sites	-	6.	
Number of Samples	-	46.	
Mean Loss on Ignition	-	24.6%	(19.5 - 29.6).
" Water/Humus Ratio	-	2.19	(1.18 - 2.74).
" pH	-	4.7	(4.4 - 5.1).
" Available Phosphates	-	6.6 mgms/100 gms	(4.1 - 13.0).
" Available Potassium	-	0.62 gms	(0.43 - 0.85).
" Exchangeable Calcium	-	0.030% Ca. (36 estimations).	(0.024 - 0.035).

Subsoils:

Site Nos.	-	13, 36 and 63.	
Number of Sites	-	3.	
Number of Samples	-	8.	
Mean Loss on Ignition	-	13.0%	(11.6 - 15.7).
" Water/Humus Ratio	-	2.05	(1.57 - 2.36).
" pH	-	5.0	(4.8 - 5.3).
" Available Phosphates	-	37.7 mgms/100 gms	(20.0 - 48.0).
" Available Potassium	-	0.44 gms	(0.24 - 0.66).
" Exchangeable Calcium	-	0.025% Ca. (5 estimations)	(0.018 - 0.032).

Soil Results for Site 38:

	n	L.I.%	W/H	pH	P_2O_5	K_2O
Topsoils	10	12.4	3.41	5.6	3.0	0.91
Subsoils	3	6.4	3.79	5.7	4.0	0.42

Sub-Type 2 - Nardus stricta on "peat"

Sites 5, 14, 15, 43 and 46

This second type of Nardus association is found on the higher slopes from 1,300 to 1,750 feet. The slopes are comparatively gentle, varying from approximately 1:6 to 1:25 on the sites investigated. In the opinion of the writer, these associations represent areas invaded and colonised by Nardus it being highly improbable that Nardus could have formed peat of such thickness. The peat would be formed by either Calluna vulgaris or Molinia caerulea. These species have now been ousted by Nardus, either owing to a change in soil conditions, or by the effect of burning and grazing.

TABLE 8

VEGETATION ANALYSIS

Percentage of Specific Frequency

Species	Site				
	5	14	15	43	46
Nardus stricta	70	85	95	90	95
Agrostis spp.	50	-	30	15	50
Deschampsia flexuosa .	60	75	75	20	60
Festuca ovina	20	20	25	-	15
Galium saxatile . ..	90	35	30	-	80
Potentilla erecta ..	10	10	15	-	5
Luzulla campestris ..	-	-	-	-	50
Carex spp.	-	-	10	-	15
Vaccinium myrtillus ..	35	20	-	35	-
Anthoxanthum odoratum	50	5	15	-	70
Festuca rubra	15	-	-	-	-
Luzula sylvatica ..	15	5	10	-	-
Molinia caerulea ..	-	15	35	10	-
Scirpus caespitosus ..	-	5	-	5	-
Juncus squarrosus ..	-	40	-	20	-
Calluna vulgaris ..	-	-	-	95	-

In all of the five sites Nardus stricta is dominant. The only other species common to all the sites Deschampsia flexuosa, which may be sub-dominant. In Site 43, Calluna vulgaris is co-dominant with Nardus. The Calluna is very short, and it seems probable on this site that the /

Photo. 16. (Site 43)

Nardus stricta on recently burned Calluna.

Photo. 17. (Site 46)

Nardus stricta community. This is an "organic" type of Nardus. The tussocks, being composed of Nardus and Deschampsia flexuosa, are large: Anthoxanthum odoratum is the principal species occurring between the tussocks.

the Nardus has increased, due to the burning of the heather. Agrostis spp., Festuca ovina, Galium saxatile, Potentilla erecta and Anthoxanthum odoratum occur in four out of the five sites. It is clear from the vegetation analysis that many of the subsidiary species are those typical of peaty soils, e.g. Molinia caerulea, Scirpus caespitosus and Juncus squarrosus - species not present in Nardus sub-type 1. Such species, however, as Agrostis, Potentilla erecta, Holcus mollis and Luzula campestris are greatly reduced in Specific Frequency percentage, or are not represented at all, when compared with sub-type 1. Luzula sylvatica is occasionally found in this association. Vaccinium myrtillus, though represented in both sub-types, is of low percentage frequency.

Soil Conditions under Nardus Sub-Type 2

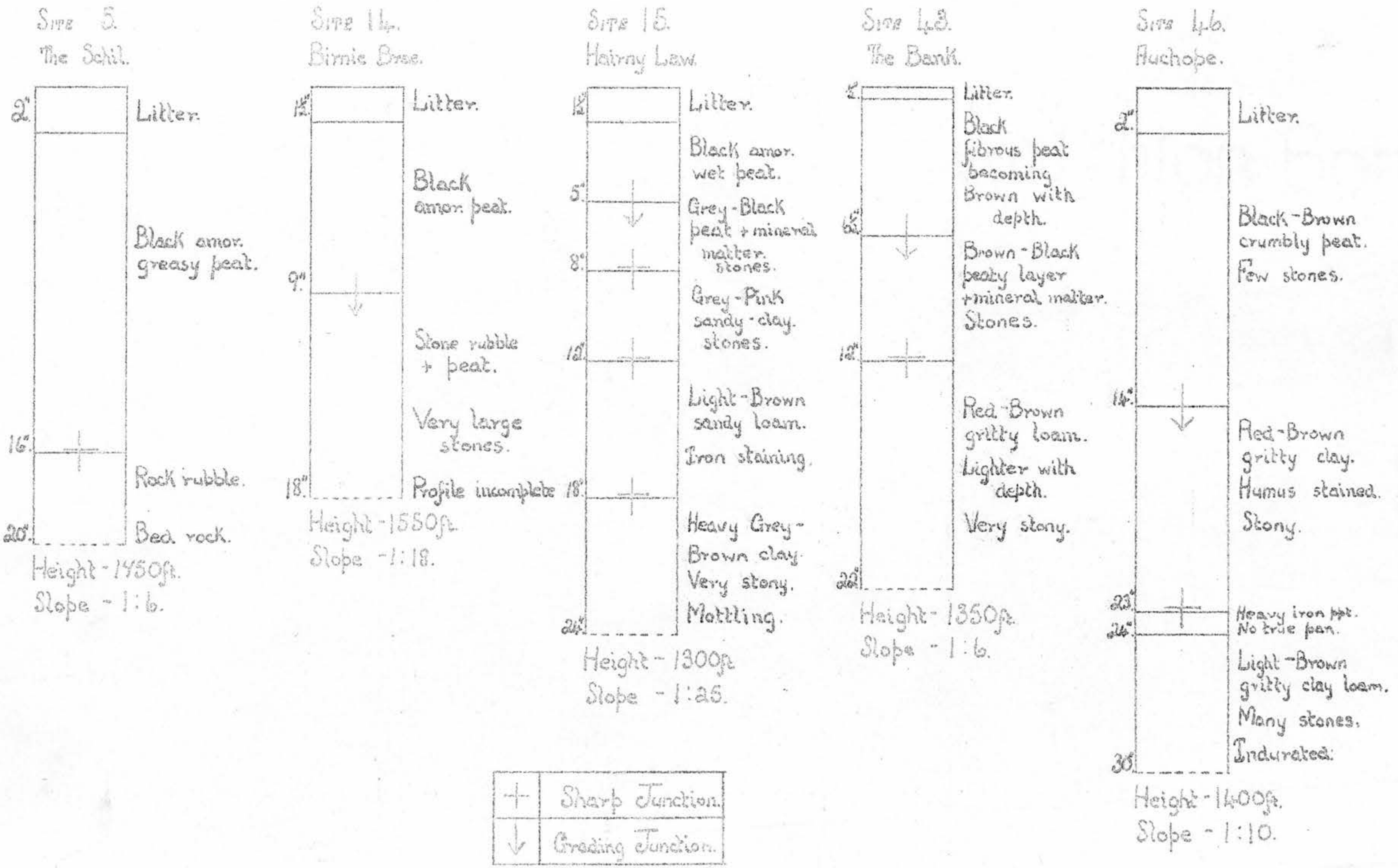
Soil Profile:

Below a litter layer ½ to 2 inches thick, all the profiles show a peat horizon 4 to 20 inches thick. The peat is pure, in some cases (Sites 5, 14 and 15) being of the black amorphous type probably accumulated by Molinia caerulea, and in others (Sites 43 and 46) being of a black-brown, crumbly type more typical of that found under Calluna vulgaris. These differentiations in peat type were made by eye, and the origin of the peat was not confirmed by plant remains.

In Site 5, the peat rests on rock rubble /

rubble underlain by the parent andesites. In Sites 14, 43 and 46, the peat horizon grades into a stony layer, 6 to 10 inches thick, containing mineral matter, roots and washed down peat. In Site 46, this horizon is a gritty, sandy clay showing much humus staining in the upper part. This profile has an incipient iron pan at 23 inches. In Site 14, the subsoil was not exposed due to the presence of a layer of very large stones at 18 inches. In Sites 43 and 46, the subsoil shows a sharp junction with the upper horizons. It is light-brown to red-brown in colour, and very stony. The texture varies from a gritty loam to a gritty clay-loam, drainage being unimpeded. In Site 15, the profile is more mature, the black, amorphous peat grading into a greyer, stony horizon 3 inches thick, containing more mineral matter. This in turn passes sharply into 4 inches of stony, grey-pink, sandy clay with roots. At 12 inches there is another sharp transition into a light-brown, sandy loam horizon with roots in the upper part and iron staining. From 18 inches onwards, the parent C horizon is a heavy, grey-brown, very stony, indurated clay showing mottling. This is the only profile in which drainage impedance was observed. As in Sites 5 and 14, the true subsoil was not reached in the profile; the subsoil figures quoted will be from Sites 15, 43 and 46 only.

NARDUS II.



Site 5.
The Schil.
2"
Litter.
Black amor. greasy peat.
16"
Rock rubble.
20"
Bed rock.
Height - 1450ft.
Slope - 1:6.
Site 14.
Birnie Brae.
1½"
Litter.
Black amor. peat.
9"
Stone rubble + peat.
Very large stones.
18"
Profile incomplete
Height - 1550ft.
Slope - 1:18.
Site 15.
Hairny Law.
1½"
Litter.
Black amor. wet peat.
5"
Grey-Black peat + mineral matter. stones.
8"
Grey-Pink sandy-clay. stones.
12"
Light-Brown sandy loam.
Iron staining.
18"
Heavy Grey-Brown clay.
Very stony.
Mottling.
24"
Height - 1300ft.
Slope - 1:25.
Site 43.
The Bank.
½"
Litter.
Black fibrous peat becoming Brown with depth.
6½"
Brown-Black peaty layer + mineral matter.
Stones.
12"
Red-Brown gritty loam.
Lighter with depth.
Very stony.
22"
Height - 1350ft.
Slope - 1:6.
Site 46.
Auchope.
2"
Litter.
Black-Brown crumbly peat.
Few stones.
14"
Red-Brown gritty clay.
Humus stained.
Stony.
23"
Heavy iron ppt.
No true pan.
24"
Light-Brown gritty clay loam.
Many stones.
Indurated.
36"
Height - 1400ft.
Slope - 1:10.
Sharp Junction.
Grading Junction.

only. The results from Sites ~~15,-43~~ 5 and 14 will be given separately at the end of this section.

Loss on Ignition:

The topsoils being highly organic, the topsoil range is a high one, from 68.2% in Site 62 to 90.7% in Site 5. The subsoil Loss on Ignition is much lower, varying from 10.0% in Site 46 to 11.7% in Site 43.

Water/Humus Ratio:

The Water/Humus ratio in the topsoils is higher than that for sub-type 1, being from 2.80 in Site 5 to 3.78 in Site 14. The subsoils are generally drier than their corresponding topsoils, the range being from 2.5 in Site 15 to 3.24 in Site 43.

pH:

The topsoil pH range is low in comparison with sub-type 1. It varies from pH 3.9 in Site 46 to pH 4.5 in Site 15. The subsoils are all less acid, the range being from 4.9 in Site 43 to pH 5.1 in Sites 15 and 46.

Available Phosphates:

From 4.7 mgms per 100 g in Site 43 to 14.0 mgms in Site 14 is the tppsoil range for phosphates in this sub type. The subsoils, though generally higher, (10.0 mgms. per 100 g in Site 46 to 11.7 mgms in Site 43) are in no way comparable with the very high sub-soil results obtained in sub-type 1.

Available Potassium:

The topsoils are reasonably high in potassium,

potassium, ranging from 0.42 g. in Site 15 to 0.84 g. in Site 43. The subsoils are all much lower than their corresponding topsoils, varying from 0.16 to 0.42 in Site 46.

Exchangeable Calcium:

Three sites were analysed for exchangeable calcium, the mean results for each ranging from 0.66% calcium in Site 5 to 0.10% in Site 14. The mean result of three subsoil samples from Site 15 is 0.033% calcium.

Summary of Results for Nardus Sub-type 2.

Topsoils:

Site Nos.	5, 14, 15, 43 and 46.	
Number of Sites	5.	
Number of Samples	45.	
Mean Loss on Ignition	83.3%	(68.2 - 90.7%)
Mean Water/Humus Ratio	3.25	(2.80 - 3.78)
Mean pH	4.2	(3.9 - 4.5)
Mean Available Phosphates	9.8 mgms/100g	(4.7 - 14.0)
Mean Available Potassium	0.63 g	(0.42 - 0.84)
Mean Exchangeable Calcium	0.081% Ca. (11 estimations).	(0.066 - 0.104)

Subsoils:

Site Nos	15, 43 and 46.
Number of Sites	3.
Number of Samples	9.

Mean Loss on Ignition:

Loss on Ignition	15.0%	(14.3 - 15.6%)
Mean Water/Humus Ratio	2.79	(2.45 - 3.24)
Mean pH	5.0	(4.9 - 5.1)
Mean Available Phosphates	10.9 mg/100g	(10.0 - 11.7)
Mean Available Potassium	0.32 g.	(0.16 - 0.42)
Mean Exchangeable Calcium	0.033% Ca.	

(3 estimations).

Results for Sites 5 and 14:

Site 5 - peat at 16 - 20 inches.

n	L.I.%	W/H	pH	P_2O_5	K_2O	Ex.Ca.%
2	84.0	3.60	4.6	5.0	0.24	---

Site 14 - stony peat (sub) at 17 inches.

n	L.I.%	W/H	pH	P_2O_5	K_2O	Ex.Ca.%
3	41.8	2.70	4.9	17.0	0.26	0.053

MOLINIA CAERULEA TYPE

The vegetation type dominated by Molinia caerulea is probably the most widespread in the area investigated. It occurs on the hill sides and on the more gently sloping hill tops, where water conditions are not limiting and flushing by spring water is absent. It appears that Molinia is associated with percolating water. This is, in all probability, surface water which seeps laterally down the slopes, and will thus be poorer in bases than water which has passed through the rock strata and issues as springs (see Photographs of north face of Park Law and south face of Fasset). It is of interest that Molinia always occurs, on slopes, which vary in the sites investigated from 1:5 to 1:25. This bears out the view of those writers, already referred to in the literature, (page 40) who contend that Molinia is associated with soil water which is moving. The associations on Sourhope are all of the tussocky type, and are burned periodically. /

TABLE 9.

VEGETATION ANALYSIS

	Site						
	10	11	12	17	37	41	42
Molinia caerulea	100	100	90	100	95	95	100
Deschampsia flexuosa ..	40	75	45	85	95	55	90
Agrostis spp.	-	-	10	40	-	50	20
Festūca ovina	75	50	25	75	15	10	25
Galium saxatile	-	5	20	10	5	50	40
Potentilla erecta . ..	-	15	20	30	5	50	40
Luzulla campestris ..	-	-	-	10	20	10	10
Poa pratensis	-	-	-	-	-	5	-
Vaccinium myrtillus ..	50	40	-	15	50	-	25
Anthoxanthum odoratum ..	-	-	-	-	50	-	25
Festuca rubra	-	-	-	-	-	5	-
Nardus stricta	75	10	45	45	5	55	20
Luzula sylvatica	15	-	20	-	-	-	-
Eriophorum vaginatum ..	15	-	-	-	-	-	-
Scirpus vaespitosus ..	-	10	-	-	20	-	-
Juncus squarrosus ..	-	20	-	5	-	-	5

Molinia caerulea is, in every case, dominant, with Deschampsia flexuosa, Festuca ovina and Nardus stricta constant species found in all seven sites. Vaccinium myrtillus, Galium saxatile and Potentilla erecta are present in five or six of the sites. Where the soil is wetter, such species as Eriophorum vaginatum, Scirpus caespitosus and /

and Juncus squarrosus are found, though in the sites investigated by the writer, these "wetter" species are of low frequency. Associations containing large amounts of Eriophorum and Scirpus were considered transitional, and thus avoided. The better grazing grasses such as Agrostis spp., Festuca rubra, Poa pratensis and Anthoxanthum odoratum are rare and are not typical of this vegetation type.

The main species present in this community can be divided into two main classes: those associated with Molinia in the tussocks, and those colonising the bare ground between the tussocks. In the former class, Vaccinium myrtillus and Nardus stricta are prominent, Nardus commonly growing in the mass of dead vegetation in the centre of the tussock. Whether this is a symptom of the degeneration of the Molinia tussock due to drying out or burning, or a normal occurrency in this district when the tussock reaches a certain size, is uncertain. With reference to degeneration of the Molinia due to drying out, the soil water figures show little correlation with the amount of Nardus present. It should be borne in mind, however, that the Nardus plant grows in a micro-habitat in the centre of the tussocks, whose water relations probably differ widely from those prevailing in the soil supporting the Molinia. Of the species colonising the bare ground between /

Photo. 18. (Site 57)

Molinia caerulea community. Vaccinium myrtillus is associated with Molinia in the tussocks. Scirpus caespitosus occurs between the tussocks.

Photo. 19. (Site 42)

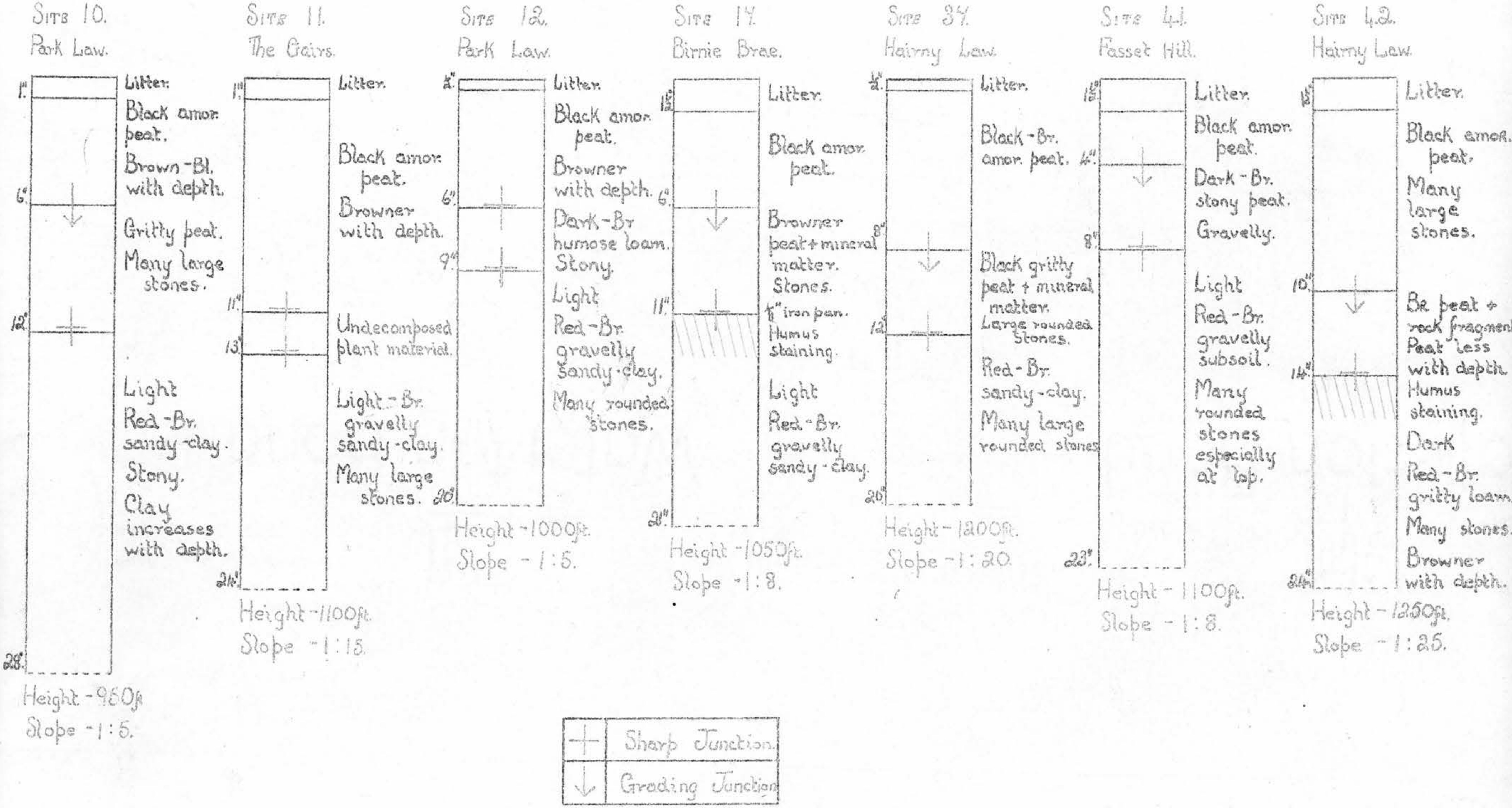
Molinia caerulea community. The tussocks are small and flat and are composed of Molinia, Nardus and Deschampsia flexuosa. Luzula campestris occurs between the tussocks.

between the tussocks, Deschampsia flexuosa and Festuca ovina are usually to be found round the bottom edges of the tussocks or between the tussocks. Luzula campestris, Potentilla erecta and Galium saxatile all grow on the peat surface between the tussocks. (See Photographs Nos. - 18 & 19).

<u>Soil Conditions under Molinia caerulea Type</u>

<u>Soil Profiles</u>: The profiles found under Molinia caerulea are very similar and are shown diagrammatically on page 162. The litter horizon is from ½ - 1½ inches thick and grades into a layer of well decomposed, black, crumbly mor humus. This type of organic matter was found in all the 21 profiles examined and is characteristic of this vegetation. It corresponds closely to the "amorphous peat" described by G. K. Fraser in his paper on "Scottish Moorlands in Relation to Tree Growth", 1933. The mor humus layer varies from 2 - 10 inches thick, normally grading from a very black form of humus in the top few inches to a browner type below. This humus is reasonably pure, though containing more mineral matter than that found in the deep peats under Calluna vulgaris. The mor humus horizon grades into a gritty, stony layer containing much humus carried down from the horizon above. This sub-humus horizon is clearly distinguished in all the profiles with the exception of Site 11, where the humus /

MOLINIA.



Site 10.
Park Law.
1"
Litter.
Black amor. peat.
Brown-Bl. with depth.
6"
Gritty peat.
Many large stones.
12"
Light Red-Br. sandy-clay.
Stony.
Clay increases with depth.
28"
Height - 950ft
Slope - 1:5.
Site 11.
The Cairs.
1"
Litter.
Black amor. peat.
Browner with depth.
11"
Undecomposed plant material.
13"
Light - Br. gravelly sandy-clay.
Many large stones.
24"
Height - 1100ft.
Slope - 1:15.
Site 12.
Park Law.
½"
Litter.
Black amor. peat.
Browner with depth.
6"
Dark-Br. humose loam.
Stony.
9"
Light Red-Br. gravelly sandy-clay.
Many rounded stones.
20"
Height - 1000ft.
Slope - 1:5.
Site 14.
Birnie Brae.
1½"
Litter.
Black amor. peat.
6"
Browner peat + mineral matter.
Stones.
11"
⅛" iron pan.
Humus staining.
Light Red-Br. gravelly sandy-clay.
21"
Height - 1050ft.
Slope - 1:8.
Site 34.
Hairny Law.
½"
Litter.
Black-Br. amor. peat.
8"
Black gritty peat + mineral matter.
Large rounded stones.
12"
Red-Br. sandy-clay.
Many large rounded stones
20"
Height - 1200ft.
Slope - 1:20.
Site 41.
Fasset Hill.
1½"
Litter.
Black amor. peat.
4"
Dark-Br. stony peat.
Gravelly.
8"
Light Red-Br. gravelly subsoil.
Many rounded stones especially at top.
23"
Height - 1100ft.
Slope - 1:8.
Site 42.
Hairny Law.
1½"
Litter.
Black amor. peat.
Many large stones.
10"
Br. peat + rock fragments
Peat less with depth.
14"
Humus staining.
Dark Red-Br. gritty loam.
Many stones.
Browner with depth.
24"
Height - 1250ft.
Slope - 1:25.
Sharp Junction.
Grading Junction.

humus and mineral horizons are divided by 2 inches of wet, undecomposed, plant material. This layer was found in all three profiles dug on this site. A sharp junction differentiates the humic horizons from the mineral subsoil, a thin iron pan being present at this junction in Site 17. The subsoils range in colour from a light to a dark red-brown, and in texture from a medium-loam to a sandy-clay. There are no visual indications of impeded drainage. The subsoil typically contains rounded stones of all sizes up to small boulders, often forming a layer in the upper part of the subsoil horizon.

Loss on Ignition: Loss on Ignition figures for the top 5 inches of soil are generally high, the main range being from 67.2% in Site 12 to 89.0% in Site 11. The figure of 43.9% for Site 41 is low owing to the very thin humus horizon (2 inches) under this association. The subsoil range is from 10.8% in Site 10 to 23.3% in Site 17.

Water/Humus Ratio: The topsoils are relatively wet when considered against the ratios obtained from the Deschampsia flexuosa and Agrostis-fescue vegetation types. The range is from 2.45 in Site 41 to 3.91 in Site 37. The subsoils vary from 1.69 in Site 17 to 3.77 in Site 11, being in most cases drier than their corresponding topsoils.

pH: Topsoil acidity is very constant in all the sites, the range being from 4.2 in Site 42 to /

to 4.5 in Site 10. The subsoils are all less acid than their corresponding topsoils, varying from 4.6 in Site 11 to 5.3 in Site 10.

Available Phosphates: Though the topsoils are highly organic in nature, the results of the phosphates analyses show a wide variation between sites. The range is from 4.7 milligrammes per 100 g. in Site 42 to 15.3 milligrammes in Site 12 - the upper part of the range indicating a supply of available phosphates unusual in a soil of this kind. The subsoil results, from 5 milligrammes in Site 11 to 20 milligrammes in Site 12, are generally higher than those estimated for the topsoils.

Available Potassium: The topsoils in this type are highly organic and the range of available potassium is high (0.41 - 0.89 g.). The subsoil range is much lower (0.18 - 0.51). It is possible that the difference between topsoil and subsoil in this case may be accentuated by the differing densities of the soils affecting the method of analysis.

Exchangeable Calcium: Sites 10, 11, 12 and 17 were estimated for exchangeable calcium percentage. The topsoil results are relatively high, having a range from 0.051% in Site 11 to 0.077% in Site 17. The subsoil results, ranging from 0.018% in Site 12 to 0.028 in Sites 11 and 17, are low, despite the rise is pH in the subsoil.

SUMMARY OF RESULTS

Topsoils:

Site Nos.	- 10, 11, 12, 17, 37, 41 and 42.	
Number of Sites	- 7.	
Number of Samples	- 71.	
Mean Loss on Ignition	- 74.9%	(43.9 - 89.0)
" Water/Humus Ratio	- 3.23	(2.45 - 3.91)
" pH	- 4.3	(4.2 - 4.5)
" Available Phosphates	- 10.1 mgms/100 gms	(4.7 - 15.3)
" Available Potassium	- 0.70 g.	(0.41 - 0.89)
" Exchangeable Calcium	- 0.068% (34 estimations)	(0.051 - 0.077).

Subsoils:

Site Nos.	- 10, 11, 12, 17, 37, 41 and 42.	
Number of Sites	- 7.	
Number of Samples	- 21.	
Mean Loss on Ignition	- 17.40%	(10.8 - 22.3)
" Water/Humus Ratio	- 2.65	(1.69 - 3.77)
" pH	- 5.0	(4.6 - 5.3)
" Available Phosphates	- 11.0 mgms/100 gms	(5.0 - 20.0)
" Available Potassium	- 0.325	(0.18 - 0.51)
" Exchangeable Calcium	- 0.023% (13 estimations)	(0.018 - 0.028)

DESCHAMPSIA FLEXUOSA TYPE

This association is found throughout the area under discussion, on the steeper, drier slopes, particularly where the soil is thin and unstable, or where the parent rock is close to the surface. It is generally confined to the higher slopes, those sites examined by the writer being between 900 and 1,300 feet, though, where the drainage is free and the slope very steep, it may be found right down to the valley bottoms. In the Cheviots, where the hills are round or flat on top, the Deschampsia flexuosa association occupies the dry zone on the steep brow of the hill, grading into damper associations above and below, where the slope is less steep and drainage conditions less exacting.

The vegetation is kept closely cropped by sheep, and presents a level appearance to the eye. This is due to the absence of tussock-forming species, though Nardus stricta occurs in scattered tufts. This type of community was treated as transitional by the writer, and was thus avoided when selecting sites.

The following Specific Frequency figures, taken on the same sites as the soil samples, show the structure and species present in this community:-

VEGETATION ANALYSIS /

TABLE 10.

VEGETATION ANALYSIS

Percentage of Specific Frequency

Species	Site					
	1	2	3	4	7	62
Deschampsia flexuosa	95	80	90	95	100	85
Agrostis spp.	80	60	20	35	70	60
Festuca ovina	60	55	70	85	60	55
Galium saxatile . ..	55	60	65	65	90	50
Potentilla erecta ..	20	-	45	50	-	20
Luzula campestris ..	10	40	75	55	35	25
Poa pratensis	20	5	-	-	10	25
Vaccinium myrtillus ..	5	10	40	75	-	15
Anthoxanthum odoratum	-	10	10	20	-	25
Holcus mollis	-	5	5	-	40	-
Carex spp.	15	-	-	-	-	5
Moss	5	35	45	45	25	45
Lathyrus montanus ..	-	-	-	-	-	10
Hieracium pilosella ..	-	-	-	-	-	15

It can be seen that Deschampsia flexuosa, Festuca ovina, Agrostis spp., Galium saxatile and Luzula campestris are common to all the communities in the analysis, with Potentilla erecta, Poa pratensis, Vaccinium myrtillus, and Anthoxanthum odoratum present in four or five of the six communities. The presence of Poa pratensis may be explained by the dunging from sheep, due to the close grazing throughout the year, and to the fact that sheep /

sheep tend to migrate to the higher slopes in the evening and their "sheep camps" or "sheep lairs" are often found in this association. Where Poa pratensis is present, Agrostis tends to be of high frequence though Agrostis does occur where Poa pratensis is absent (Sites 1, 2, 7 and 62). Nardus is not present, and in all cases Deschampsia flexuosa is dominant, though Festuca ovina may increase to the role of a co-dominant rather than a sub-dominant. Vaccinium myrtillus is commonly found on the steepest slopes in this association, particularly on the drier facies, and tends to be most abundant when Agrostis is of low frequency (Sites 3 and 4). This same trend is shown by Luzula campestris (Sites 3 and 4), and Potentilla erecta. Galium saxatile remains remarkably constant throughout. Carex spp. are sometimes found in the damper facies where the affinities of the association are tending towards that of the Agrostis-fescue type.

Soil Conditions and Type under Deschampsia flexuosa Association

Profile:

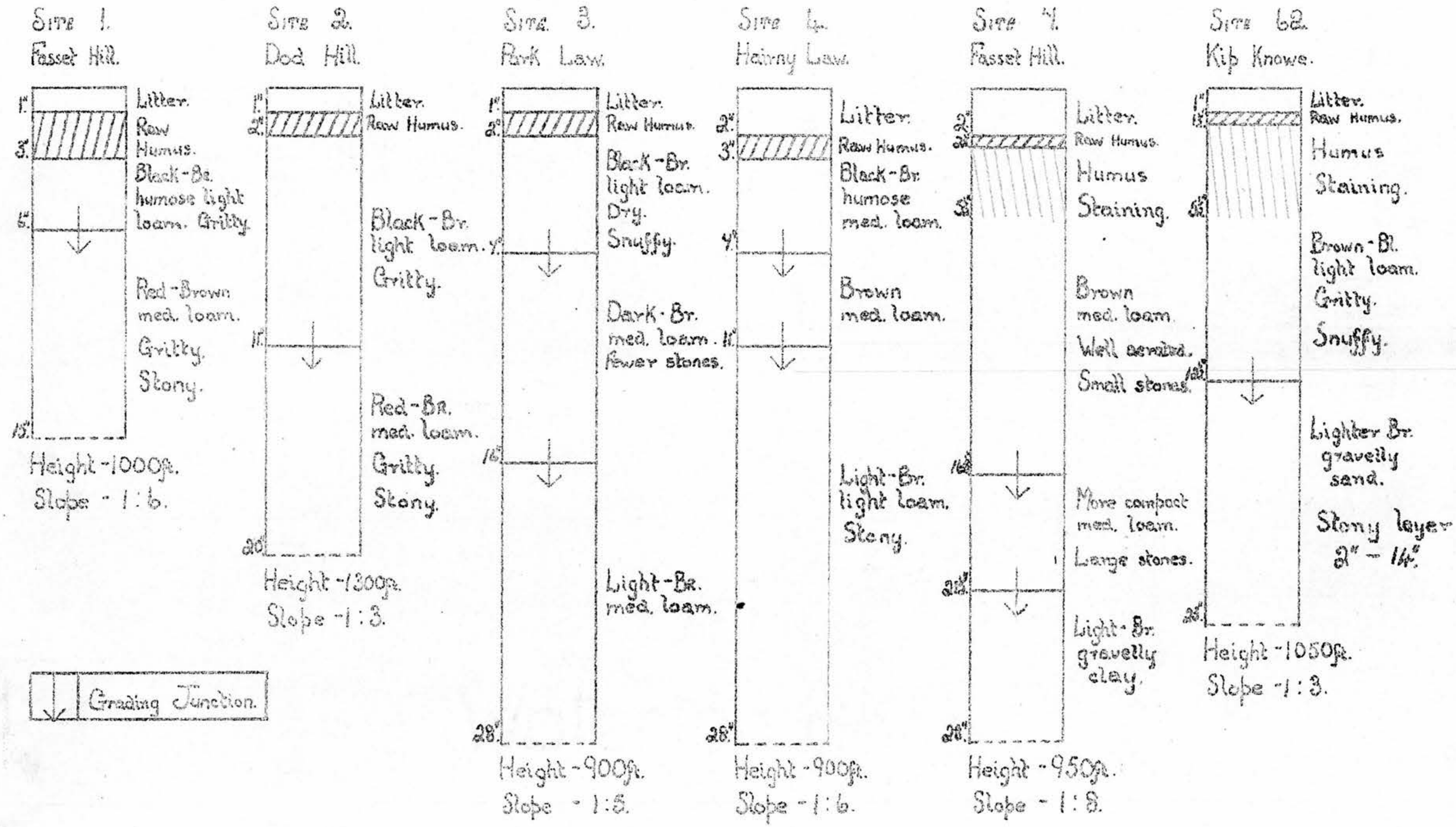
The soil profiles under this association were found to be generally similar in the six sites examined. In all, eighteen profiles were dug, three in each site, and the type for each site is represented diagrammatically on ~~Figure~~ Page 170.

In /

In every case a raw humus layer from ½ to 2 inches thick was evident, overlaid by a layer of undecomposed material or litter up to 2 inches thick. (On no occasion was this association found on peat, nor is there any evidence that peat has at one time been present and subsequently removed by erosion - the Deschampsia flexuosa association colonising the eroded surface.)

Below the raw humus layer, the profiles are all free-draining and rest on an open, gritty subsoil composed mainly of angular rock fragments. On the steepest slope (Sites 2 and 62) and in Site 1, where the slope is less but which occupies the brow of the more gently sloping Fasset Hill, the soils are of a residual type, being shallow and very stony throughout. The stones vary in size and are angular in shape and fresh in colour, indicating that they have been derived from the parent rock in situ and have not been transported. Sites 3, 4 and 7 show a deeper type of profile, their positions being such that they have collected a certain amount of hill wash from above. They are, however, still very dry, and show the same angular, fresh stones and the typical, open, stony subsoil. All the profiles have a mineral-organic layer immediately below the raw humus. This is most clearly shown in Sites 1, 2 and 4, though it is present in 3, 7 and 62 but is less highly developed. /

DESCHAMPSIA.



developed. Soil horizons between the organic sub-surface layer and the true subsoils are found in Sites 3, 4 and 7, the maximum development being in Site 7 in contrast to Sites 1, 2 and 62, where the "organic" layer lies directly on the subsoil.

The soils are all immature, and, apart from the junction between the raw humus and the organic layer, the horizons grade into one another with no clear line of differentiations

Deschampsia flexuosa Type - Soils

In all, eighty-two soil samples were taken from this vegetation type, of which sixty-one were top-soils and twenty-one subsoils. The mean results for each site are shown ~~in the following table.~~ as follows:-

Loss on Ignition:

The Loss on Ignition figures varied in the top-soils from 18.90% in Site 3 to 33.70% in Site 2. The humus was all of the black, crumbly, structureless, mull type, forming a clearly defined layer in the upper 2 inches of the soil, but also showing some distribution into the afore-mentioned gritty-organic layer beneath. The subsoils also show a relatively high Loss on Ignition, ranging from12.8% in Site 62 to 18.5% in Site 4. Some allowance must be made for the higher percentage of clay in the subsoils, which will tend slightly to exaggerate the Loss on Ignition figures and some fine roots which are found at the depth at which the subsoil samples were taken. /

taken.

Water/Humus Ratio:

The Water/Humus ratios show that with the exception of Site 1 the soil is very dry. The Specific Frequency figures for this site, however, show 95% Deschampsia flexuosa present. No marked variation in any of the other soil characteristics suggest that it is out of place. The range shown for topsoils (excluding Site 1) is a small one - 0.90 in Site 4 to 1.84 in Site 2 - and for the subsoils, from 1.65 in Site 4 to 2.90 in Site 62. It will be noticed that the subsoil is in all cases "wetter" than the topsoil for the same site.

pH:

pH is also very constant throughout the type, ranging from 4.41 in Site 3 to 4.93 in Site 62. As can be seen in the Table, the main range is between 4.4 and 4.6. In comparing the pH results for topsoils and subsoils, it can be seen that the subsoil is always less acid - in some cases quite markedly so, as in Site 2, where there is a difference of almost 1 pH unit. The subsoil range is from 4.9 to 5.5.

Exchangeable Calcium:

Contrary to what might be expected from the pH fesults, the exchangeable calcium figures do not generally increase with depth. Of the five sites for which exchangeable calcium /

calcium estimations were made, Sites 2 and 4 show a higher percentage of exchangeable calcium in the subsoil, Site 7 shows the same amount in each, and Sites 1 and 3 show less exchangeable calcium than that found in the topsoil. The variation within the topsoils is small (0.023% - 0.037%), as compared with that shown by the subsoils (0.022% - 0.050%).

Available Phosphates:

Available Phosphates show little change with depth, in all but two sites being the same in topsoil and subsoil. In Site 7, the subsoil has a slightly higher value for phosphates, and in Site 62, the subsoil is very much higher (Topsoil 5.2, Subsoil 17 m.g. per 100 g.). The high subsoil values obtained for available phosphates have been found in many of the sites and will be discussed at a later stage. (page 195).

Available Potassium:

Potassium shows little change in the topsoils, the range being only from 0.61 to 0.89 g., and in all cases is the same as, or higher, than the amount estimated for the corresponding subsoil. The subsoil range is 0.33 - 0.67.

SUMMARY OF RESULTS

Topsoils:

Site Nos. - 1, 2, 3, 4, 7 and 62.

Number of Sites /

Number of Sites	- 6.	
Number of Samples	- 61.	
Mean Loss on Ignition	- 25.8%	(18.9 - 33.7).
" Water/Humus Ratio	- 1.49	(0.90 - 2.77).
" pH	- 4.59	(4.41 - 4.93).
" Available Phosphates	- 11.0 mgms	(5.2 - 18.0).
" Available Potassium	- 0.71 g.	(0.61 - 0.89).
" Exchangeable Calcium	- 0.031% (46 estimations).	(0.023 - 0.037).

<u>Subsoils</u>:

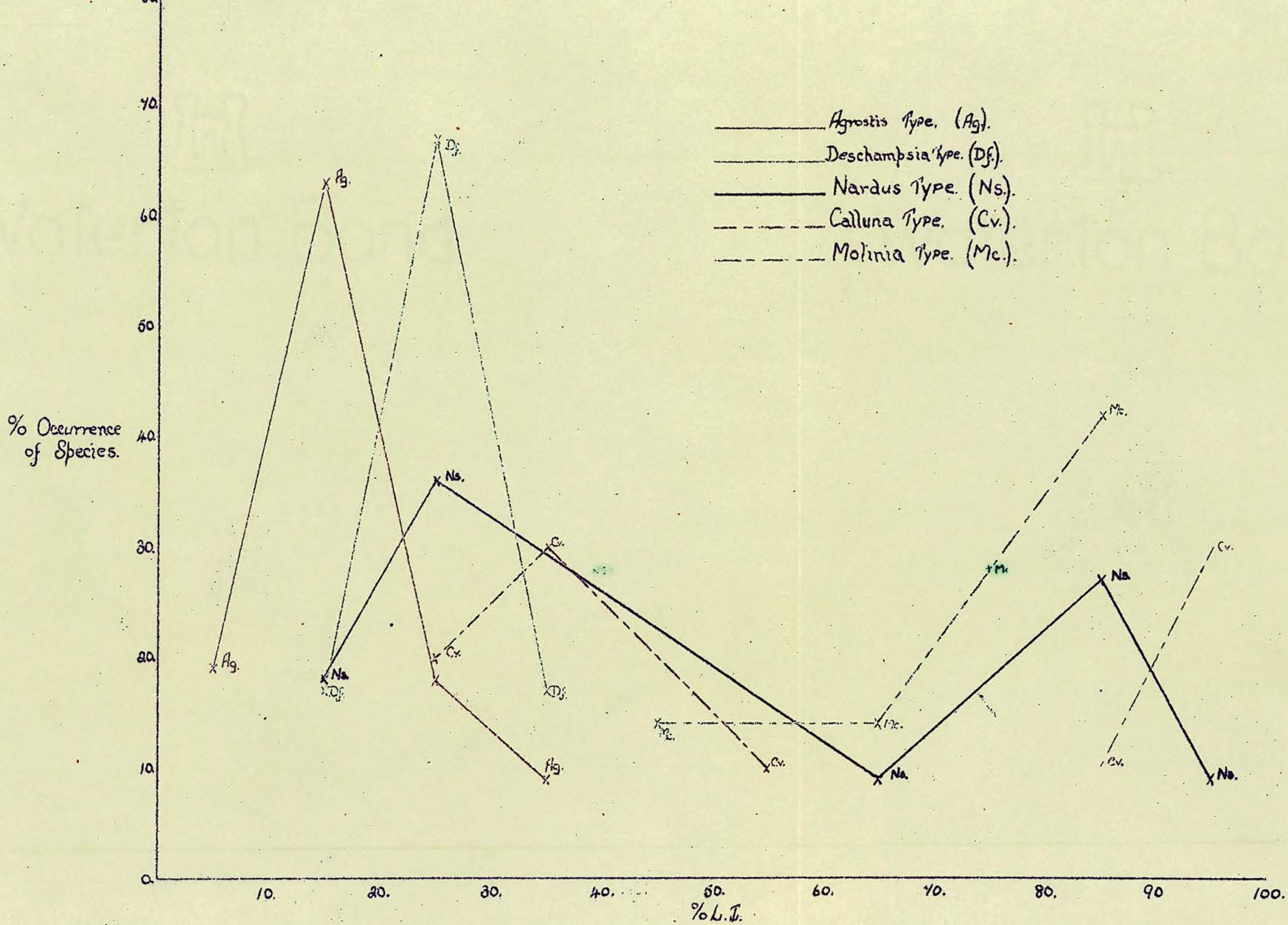
Site Nos.	- 1, 2, 3, 4, 7 and 62.	
Number of Sites	- 6.	
Number of Samples	- 19.	
Loss on Ignition	- 14.7%	(10.9 - 18.5).
Mean Water/Humus Ratio	- 2.3	(1.7 - 2.9).
" pH	- 5.1	(4.9 - 5.5).
" Available Phosphates	- 13.8 mgms	(8.0 - 23.0).
" Available Potassium	- 0.51 gms	(0.33 - 0.67).
" Exchangeable Calcium	- 0.033% Ca. (16 estimations).	(0.021 - 0.051).

PERCENTAGE OCCURRENCE OF VEGETATION TYPES IN RELATION TO PERCENTAGE LOSS ON IGNITION

In Graph 1, page 176, the percentage occurrence of the five main vegetation types in relation to percentage Loss on Ignition is shown diagrammatically. The percentage figures on the perpendicular axis of the graph, refer to the percentage of the total number of sites investigated for each vegetation type which occurs within a 10% range of O.M. Thus, 19% of the eleven Agrostis sites investigated occur between 0 - 10% L.I., etc.

This graph clearly shows the twin L.I. ranges of Calluna vulgaris and Nardus stricta types already referred to in this section. Molinia caerulea is confined to the "organic" soils, and Deschampsia flexuosa and Agrostis spp. types are found only on the "mineral" soils - the latter type preferring a soil of lower L.I. than the Deschampsia flexuosa type.

GRAPH 1.


Agrostis Type. (Ag).
Deschampsia Type. (Df).
Nardus Type. (Ns).
Calluna Type. (Cv).
Molinia Type. (Mc).
% Occurrence of Species.
%L.I.
0.
10.
20.
30.
40.
50.
60.
70.
80.
90
100.
Ag.
Df.
Ns.
Cv.
Mc.

Percentage Exchangeable Calcium with Reference to the Principal Vegetation Types.

This section deals with the results obtained for the percentage of exchangeable calcium present in the soils under the main vegetation types. The method of analysis was that used by Rice Williams and is described in Appendix lV (p286). As the analysis process is a lengthy one, all the samples taken could not be estimated. Table 11 below gives the mean results of the analyses of 218 topsoils and ~~[illegible]~~ 63 subsoils.

Table 11

	Topsoils		Subsoils	
Veg. Type	Mean Ex. Ca.%	n	Mean Ex. Ca.%	n
Agrostis 1 (no Gleying)	0.069	28	0.091	9
Agrostis 2 (Gleying)	0.111	30	0.081	7
Calluna 1 (Organic)	0.044	13	0.002	3
Calluna 2 ('Mineral')	0.023	20	0.004	4
Nardus 1 ('Mineral')	0.030	36	0.025	5
Nardus 2 ('Organic')	0.081	11	0.043	6
Molinia caerulea	0.068	34	0.023	13
Deschampsia flexuosa	0.031	46	0.033	16

The method of estimation of exchangeable calcium has the same defect as that encountered in the estimation of available phosphates and potassium. 20 g. of air-dry soil were used but, owing to the large amount of organic material present in many of the samples, the volume of soil used differed greatly. It is obvious from Table 11 that the results for

for Calluna 1, Nardus 2 and Molinia - all organic soils - are markedly higher than those obtained for the more mineral soils, with the exception of Agrostis. It is further considered that in the 'Organic' soil type, though the analytical results are higher for exchangeable calcium than the mineral soil, base saturation will in fact be lower owing to the large amounts of colloidal material present. In Table 12, the exchangeable calcium results have been multiplied by 1000 and divided by the percentage L.I. Assuming that the percentage L.I. is equal to the amount of organic colloids, (the clay percentage of the topsoils is very low), the value obtained will in essence be a measure of the degree of base saturation.

Table 12.

	$\frac{\text{Ex. Ca. x 1000}}{\%\text{L.I.}}$	Topsoils n
Agrostis 1	3.52	28
Agrostis 2	6.17	30
Calluna 1 (organic)	0.49	46
Calluna 2 (mineral)	0.56	13
Nardus 1 (mineral)	1.22	20
Nardus 2 (organic)	1.02	36
Molinia	0.92	11
Deschampsia	1.16	34.

From Table 12, it can be seen that the difference in the results due to organic matter has been removed and that in terms of base saturation, the organic orgaȟic soils are generally lower than the mineral soils. The degree of saturation of Molinia, Deschampsia and Nardus 1 and 11 is similar. The two Calluna types are very low and the Agrostis soils very high - particularly the gleyed Agrostis type 2.

From Table 11, the exchangeable calcium status of the subsoils may be seen. As the L.I. for the subsoils is low in every case, these results are comparable. The two Nardus types, Molinia and Deschampsia are again similar, being relatively low in exchangeable calcium. The Calluna subsoils are extremely low, indicating severe leaching and podsolization. The Agrostis soils are relatively high, doubtless owing to the addition of bases from the mineral spring water. The highest degree of base saturation is found in the gleyed Agrostis soils. It has already been shown that Trifolium repens is found in greatest abundance in the Agrostis 2 type, and it appears likely that relatively high base saturation is an important factor in the distribution of this species in the uplands.

Reviewing the exchangeable calcium results, it can be seen that for the topsoils, the differing amounts of organic matter make impossible an immediate comparison of results. The results are therefore expressed in terms of base saturation, the Agrostis soils having the highest and the Calluna the lowest degree of saturation. The subsoil results/

results show a similar trend, and the very low figures for the Calluna subsoils are of particular interest. It may be significant that wild white clover occurs most commonly in the soil group where base saturation is highest.

SECTION 5

INTER-RELATION OF VEGETATION TYPES

THE INTER-RELATIONS OF THE FIVE MAIN VEGETATION TYPES WITH REFERENCE TO SPECIES AND SOIL CONDITIONS

1. Distribution of five main vegetation types in relation to:-

Loss on Ignition of the Topsoils

The distribution of the five main vegetation types in relation to topsoil percentage Loss on Ignition is shown in the histograms on page 199. The mean percentage Loss on Ignition for each site is plotted against the number of sites occurring in each percentage group.

The soils of Sourhope fall into two main categories when considered against Loss on Ignition figurees, namely (1) above 60%, and (2) below 40%. As can be seen from the histograms, only two from the forty-six sites plotted have mean Loss in Ignition figures between 40 and 60%. These two categories refer to what might be termed in the first case "mineral" hill soils, and in the second "organic" hill soils. In the "mineral" hill soil, sub-litter (A1) organic horizons are very thin or are absent altogether, and active peat formation is not taking place. In the "organic" hill soils, the sub-litter organic horizon is well developed - in some cases it may be many feet thick - and peat formation is still in progress. The "gap" in the Loss on Ignition results from 40 - 60% is of interest.

interest. As transitional vegetation types were avoided, the sites selected probably fall into the two main categories of "mineral" and "organic" soils. As has been already shown, the transition from peat to mineral soil on Sourhope is usually a sharp one. In the opinion of the writer, if these narrow transitional areas be excluded, the soils of Sourhope fall into the two main categories under 40% Loss on Ignition and over 60% Loss on Ignition. Unless there is a marked climatic change, it seems unlikely that any area now of the "mineral" type will ever become an area of active peat formation and vice versa.

The occurrence of the five vegetation types is closely related to the two main soil categories. The Deschampsia flexuosa and Agrostis-fescue communities are confined to the "mineral" soils. Both vary from 10 to 40% Loss on Ignition, the main zone of occurrence for the Agrostis type ranging from 10 to 20% Loss on Ignition, and the Deschampsia flexuosa type from 20 to 30% Loss on Ignition. Molinia caerulea is confined to the "organic" soils, its principal range being from 60 to 90% Loss on Ignition, with a peak between 80 and 90% Loss on Ignition. Molinia is never found on a mineral soil. Calluna vulgaris and Nardus stricta are interesting in that they occur in both the main soil categories. Both vegetation types show twin ranges of 10 - 30% Loss on Ignition/

Ignition and 80 - 100% Loss on Ignition. These coincide with the sub-types already distinguished by means of the soil profile characteristics for Calluna and Nardus. The twin range of Nardus stricta also shows why this species is such a successful coloniser of over-grazed grass-heaths or burned and over-grazed heather. The mineral soil under the former type and the mineral or organic soil under the latter provide a favourable medium for the growth of Nardus stricta.

From these results, it may be concluded that between 10 and 40% Loss on Ignition, organic matter is not the limiting factor on the growth of Calluna vulgaris, Nardus stricta, Agrostis species and Deschampsia flexuosa. The Agrostis type, however, shows a preference for a soil between 10 - 20% Loss on Ignition, while the other three vegetation types have their optima between 20 - 30% Loss on Ignition. At the other end of the Loss on Ignition range, Molinia caerulea, Calluna vulgaris and Nardus stricta types occur. No associations of the Agrostis or Deschampsia flexuosa types are found between 60 - 100% Loss on Ignition.

Water/Humus Ratioof the Topsoils

The distribution of the five main vegetation types with reference to the water/humus ratio is shown diagrammatically on page 199. The horizontal axis has been grouped into units of 0.5 Water/Humus.

Water/Humus.

As would be expected when dealing with a factor such as water, the histograms show a continuous range for each vegetation type and no preliminary grouping into categories can be made, as was possible with the Loss on Ignition figures. The driest and most restricted range is shown by Deschampsia flexuosa. This type, with its optimum occurrence between 1.0 - 1.5 Water/Humus, has a principal range from 0.5 - 2.0. The histogram closely resembles that obtained for Loss on Ignition for this type. The site occurring between 2.5 - 3.0 is not considered typical by the writer, and as previously mentioned, Water/Humus and vegetation analysis results indicate that it is probably transitional to the Agrostis-fescue type. The Molinia caerulea type also exhibits a narrow Water/ Humus range. Varying from 2.0 - 4.0, this factor corresponds to the constant soil type already shown to be characteristic of the community, and borne out by the Loss on Ignition results. Despite the variation in Loss on Ignition results for the Calluna vulgaris vegetation type, its main Water/ Humus range is restricted from 2.5 - 4.5. Although Calluna occurs on both the main soil categories, the Water/Humus range is even, showing no peaks. Nardus stricta, however, has a very definite Water/Humus peak between 2.5 - 3.0. The "wettest" soils on which it occurs /

occurs (Water/Humus 4.0) compare closely with the upper limits of Callùna and Molinia. The term "wet" as applied to soils, refers to the relative amount of water present when the humus content is taken into consideration i.e. the Water/Humus ratio. The lower limit of Water/Humus 1.0, however, indicates that Nardus can grow on soils too dry for either Molinia or Calluna, i.e. soils within the range of the Agrostis and that of the Deschampsia flexuosa type. Of the five vegetation communities investigated, the Agrostis type shows the widest range of Water/Humus results, though it must be remembered that this type includes the very wet soils dominated by Deschampsia caespitosa. The very wide even Water/Humus range (1.0 - 5.0) suggests that within the Agrostis type the main vegetational differentiation is related primarily to the amount of water in the soil.

From the Water/Humus histograms, it would appear that, in the Sourhope area, Calluna and Molinia occur on soils of essentially similar wetness, the range being small. The Deschampsia flexuosa type also has a narrow, but very dry, range which typically does not overlap that of the Calluna or Molinia types. The Agrostis vegetation type has a very wide range of water tolerance, embracing those of the other four main vegetation types, yet showing distinct vegetational changes within itself/

itself depending on soil water content. Nardus stricta, though showing a preference for soils of Water/Humus from 2.5 - 3.0, has a Water/Humus range from 1.0 - 4.0. This overlaps the range of the other four vegetation types and indicates that water content of the soil must seldom be the limiting factor to its spread.

pH Relations of the Topsoils to Vegetation

The distribution of the five main vegetation types in relation to topsoil pH is shown in the histograms on page 199. The horizontal scale has been grouped into 0.2 pH units.

The lowest range of the five types (3.6 - 4.2) is shown by Calluna, the largest number of sites being between 3.6 - 3.8. The Molinia caerulea type is slightly less acid than the Calluna type, ranging from pH 4.0 - 4.6. Molinia has a definite acidity peak, five out of the seven sites investigated occurring between pH 4.2 - 4.4. As was found for Loss on Ignition and Water/Humus, Deschampsia flexuosa has a narrow acidity range, the results obtained giving pH's between 4.2 - 5.0. Four out of the six sites investigated are between pH 4.4. - 4.6. The Agrostis type is the least acid of the five main vegetation types, having a range of 1 pH unit between 4.8 - 5.8. Six out of the eleven sites comprising this type occur between pH 4.8 - 5.0. Nardus stricta has again the broadest tolerance of acidity of the five /

five types, occurring between 3.8 - 5.8. Its principal acidity range, however, is from 4.2 - 4.8. It is of interest, when the pH results are related to the two major soil types, that, although Nardus has a pH range which includes both the more acid organic soils and the less acid mineral soils, Calluna pH's are all typically low irrespective of soil type.

A consideration of the five histograms shows that Molinia caerulea, Deschampsia flexuosa and Calluna vulgaris vegetation types colonise soils of narrow pH range. Calluna is the most acid, growing chiefly on soils more acid than those found under any other vegetation type, with the exception of Nardus. Deschampsia flexuosa and Molinia caerulea, though colonising soils of markedly different profile, are very similar in acidity range. The Agrostis type indicates soils of a relatively high pH, the range overlapping only on the upper limit of the Deschampsia flexuosa type, and being quite independent of either Calluna or Molinia. As was found when discussing Loss on Ignition and Water/Humus Ratio, the only vegetation type whose range impinges on those of the other four vegetation types, is that dominated by Nardus stricta. This particularly applies to Molinia and Deschampsia, whose acidity range from 4.2 - 4.6 coincides with the major range of occurrence of Nardus. It is thus evident, that, in the /

the role of an invader of other vegetation types, Nardus can tolerate the acidity conditions prevailing in the other four vegetation types. Only at the two extremes of the acidity range, i.e. under pH 3.8 and over 5.2, is it possible that soil acidity may become important as a factor controlling the presence of Nardus.

Available Phosphate Relations of Topsoils to Vegetation Type

The distribution of the five major vegetation types in relation to available phosphates is shown in the histograms on page 199. The horizontal scale has been grouped in units of 2 milligrammes of available phosphates per 100 g. of air-dry soil.

From the histograms it can be seen that the amounts of phosphates vary greatly within each vegetation type, and for this reason, it is difficult to draw up range figures for each type. This wide scatter of results may be due to one of two reasons. The soils may in fact contain very variable amounts of phosphates. This seems unlikely when the constancy of the other soil factors is considered. Secondly, the method of phosphate estimation may be suspect. The method used, which is fully described in the Appendix IV page 286, is the one used for the routine analysis of arable soils. These soils are normally between pH 5.0 - 7.0 and for this range the results /

results obtained are reasonable accurate. As has been shown, very few of the soils analysed for this work are above pH 5.0. It is possible that most of the phosphates present in these acid hill soils will be in the form of iron and aluminium or organic phosphates - a form unavailable to the plant. In view of the very high results obtained for many of the soils estimated, it appears that, owing to the very low pH of the HCl extraction process used, some of these iron and aluminium phosphates have been estimated as "available". It should also be borne in mind that, in the method of phosphate estimation, 5 g. of air-dry soil are used. Where the soil is highly organic, the volume of soil used to give a standard weight will thus be very much more than that for a mineral soil. This may also tend to give "high" results.

In view of what has been said about the possible short-comings in the method of the available phosphates estimations, little can be drawn from the histograms apart from a few general trends. As the Agrostis vegetation type colonises soils of relatively high pH and low organic matter, the results obtained will be reasonably accurate. The eleven sites show a range from 3 - 9 mg. P_2O_5 per 100 g. of air-dry soil. By arable standards these soils vary from "Low" to "Medium" with regard to phosphate status. The Nardus range from 3 to 15 mg. has two distinct peaks. /

peaks. These do not correspond to the two types of Nardus already distinguished. The results for Calluna, which vary from 3 to 11 mg., again show little correlation with soil type, though the results from the deep peat type of Calluna all occur between 3 and 7 mg. Theoretically phosphates should be higher in an acid mineral soil than in a peat soil of similar pH. In the acid mineral soil the phosphates will be combined mainly with aluminium and iron, whereas in the peaty soil most of the phosphates will be in an organic form. Molinia, ranging from 3 to 17 mg., shows a very wide scatter of results. Deschampsia flexuosa, although occurring on a "mineral" soil of relatively low Loss on Ignition gives a wide variation in phosphate results. Three of the six sites comprising this vegetation type occur between 9 and 11 mg., which is, however, of little value when the distribution of the remaining three sites is considered.

Available Potassium Relations of Topsoils to Vegetation Type.

The histograms on page 199 show the distribution of the five main vegetation types with reference to available potassium. The horizontal scale /

scale is divided into units of 0.1 g. The results are expressed as the weight of mycelium of Aspergillus niger formed after a five day incubation period. The method is fully described in the Appendix page 286. By arable standards the weight of mycelium is related to soil potassium status as follows:-

0.25 gms. and below	-	Very Low
0.25 - 0.30 g.	-	Low
0.31 - 0.35 g.	-	Medium Low
0.36 - 0.45 g.	-	Medium
0.46 - 0.70 g.	-	High
0.71 g. and above	-	Very High

The method is subject to the same organic matter effect as was found in the phosphate estimation, a fixed weight of soil being used. The results are, however, more uniform than those for phosphates as is indicated by the histograms. The Agrostis type forms a compact block between 0.5 - 0.8 g. No differentiation can be made between the two vegetation sub-types composing the Agrostis type. The other completely "mineral" soil type, that of Deschampsia flexuosa, shows a range from 0.6 - 0.9 g. with a peak between 0.6 and 0.7 g. The constant "organic" soil type, Molinia, has a wide and dispersed range from 0.4 - 0.9 g. Calluna, showing a very marked peak between 0.7 and 0.8 g., is consistently high in available potassium,

potassium, ranging from 0.7 - 1.1 g. It may be significant that the two sites giving mean potassium results between 0.9 and 1.1 g. are both of the deep peat types. Nardus stricta, though showing no potassium correlation with the "mineral" or "organic" soil types on which it occurs, has the widest range of all the five vegetation types (0.4 - 1.0 g.).

SUMMARY

From a general review of the histograms, the most interesting single point to emerge is the range of tolerance exhibited by Nardus stricta. In every case its range overlaps that of the four other vegetation types. This indicates that, in the South-East of Scotland, soil conditions, - especially percentage Loss on Ignition, water content and acidity, - can seldom be the factor limiting the spread or colonisation of bared ground by this species. Calluna, with its twin range of soil types, is typically very acid and appears to be very high in available potassium. As would be expected from the consideration of soil profiles, Molinia and Deschampsia flexuosa show a restricted range of soil conditions. The Agrostis vegetation type, which provides the best grazing land on the farm, is clearly differentiated by its much lower acidity status. This doubtless explains the presence of the /

the broad leaved grass species and wild white clover.

Relation of Vegetation Type to Subsoil Conditions

1. Loss on Ignition:-

As would be expected with a soil factor such as subsoil Loss on Ignition, the vegetation types show a constant range throughout. The histograms on page 200, indicate this to be 0 - 30%. In these histograms only true subsoil figures have been used, sites being excluded where the profile was incomplete.

2. Water/Humus Ratio:-

The histograms for top and subsoil Water/Humus show a similar range for each vegetation type and, though no hard and fast rule can be made, the subsoils are usually slightly wetter than the corresponding topsoils. The Agrostis type as a result of the varying amounts of clay present in the subsoil again shows the widest range from 2.0 to 5.0.

3. pH:-

This factor is one of the most interesting in the comparison between topsoil and subsoil. In the histograms on page 200, the subsoil acidity relations are shown, the horizontal scale being graduated in divisions of 0.2 pH units.

The most obvious contrast between the acidity of topsoil and subsoil is the reduced acidity /

acidity in the latter. In every case the subsoil is less acid than the topsoil, a comparison of pH range figures clearly illustrating this. The Agrostis type shows the smallest difference, though the peak in the subsoil is from pH 5.4 - 5.6 as against 4.8 - 5.8 with a peak between 4.8 and 5.2. Deschampsia flexuosa slightly overlaps its topsoil range, varying from 4.8 - 5.6. The acidity of the Molinia type decreases to pH 4.6 - 5.4. The largest variation between topsoil and subsoil is exhibited by the Calluna type. Here the subsoils have a higher, but still narrow pH range between 4.6 and 5.2. The complete subsoil range of acidity is less than that for the topsoils:- 4.6 - 6.2 as compared with 3.6 - 5.8 for the topsoils.

4. Available Phosphates:-

Although when dealing with subsoils the effect of organic matter on phosphates analysis is removed, that of iron and aluminium phosphates is increased. With the exception of the Agrostis range of soils, those of Sourhope are subject to some degree of podsolization. This suggests that sesquioxides are being removed from the eluvial surface horizons of the soil and are being precipitated in the subsoil, and increases the probability that the subsoil phosphates will be in the iron or aluminium form. /

form.

The subsoil distribution of phosphates is shown in the histograms on page 200. The horizontal scale is graduated in divisions of 10 mg. of available phosphates per 100 g. of air-dry soil.

The Agrostis vegetation type is apparently lower in phosphates than any of the other four types investigated. As podzolisation in these soils is low it is probable that the histogram presents a fairly true picture of the available phosphate status in these subsoils. For this type there is little variation between topsoil and subsoil. This also holds true for the Molinia and Deschampsia types, the topsoil results comparing with those obtained from the subsoils. Six of the eight Nardus sites have mean subsoil phosphate figures between 10 and 20 mg. Two sites, however, show mean results between 40 and 50 mg. (The six samples providing the mean figures for these two sites were check estimated.) Similar very high phosphate results are found for the Calluna type - particularly as already noted, under the "thin mor" type. It would be of interest to ascertain whether the amount of sesquioxides in the subsoils under acid hill soils showed a wide variation and whether any correlation could be made between high sesquioxide content and high "available" phosphates./

phosphates.

5. Available Potassium:-

Unlike phosphate, available potassium tends to be high in the topsoils and low in the subsoils. This is clearly shown by the histograms depicting available potassium in the subsoils under the five main vegetation types on page 200. The horizontal scale is divided into units of 0.1 g. As the subsoils are all low in organic matter, the results for available potassium are comparable under all the vegetation types.

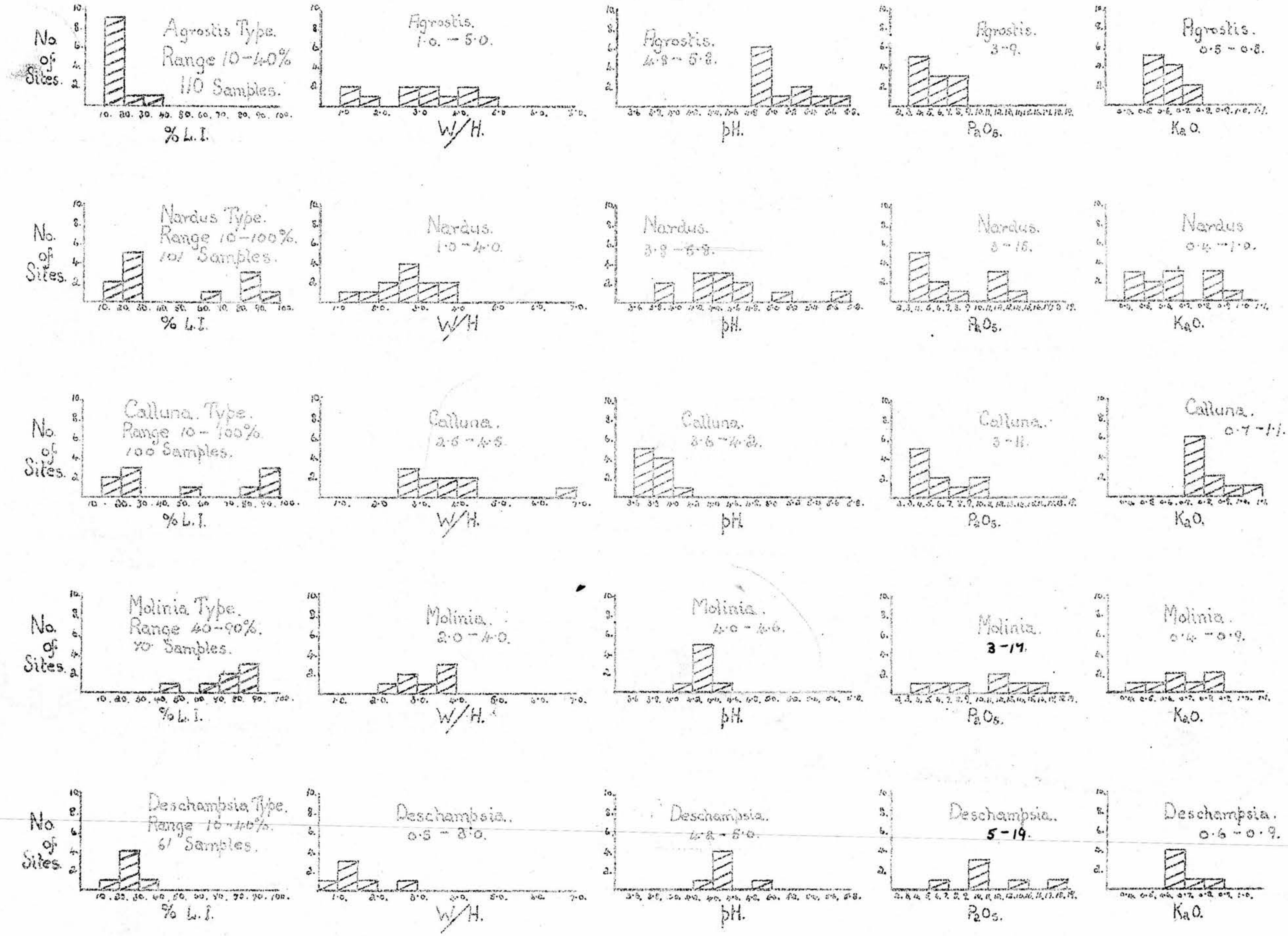
The Agrostis type of soils is lowest in potassium, the range being from 0.3 - 0.6 g., with a peak between 0.3 and 0.4 g. A similar range is shown by Calluna, the peak in this case being between 0.5 and 0.6 g. Deschampsia has an even range from 0.3 - 0.7 g. The widest ranges are shown by Molinia (0.1 - 0.6 g.) and Nardus (0.1 - 0.7 g.). Four out of the seven Molinia sites occur between 0.1 and 0.3 g.

SUMMARY

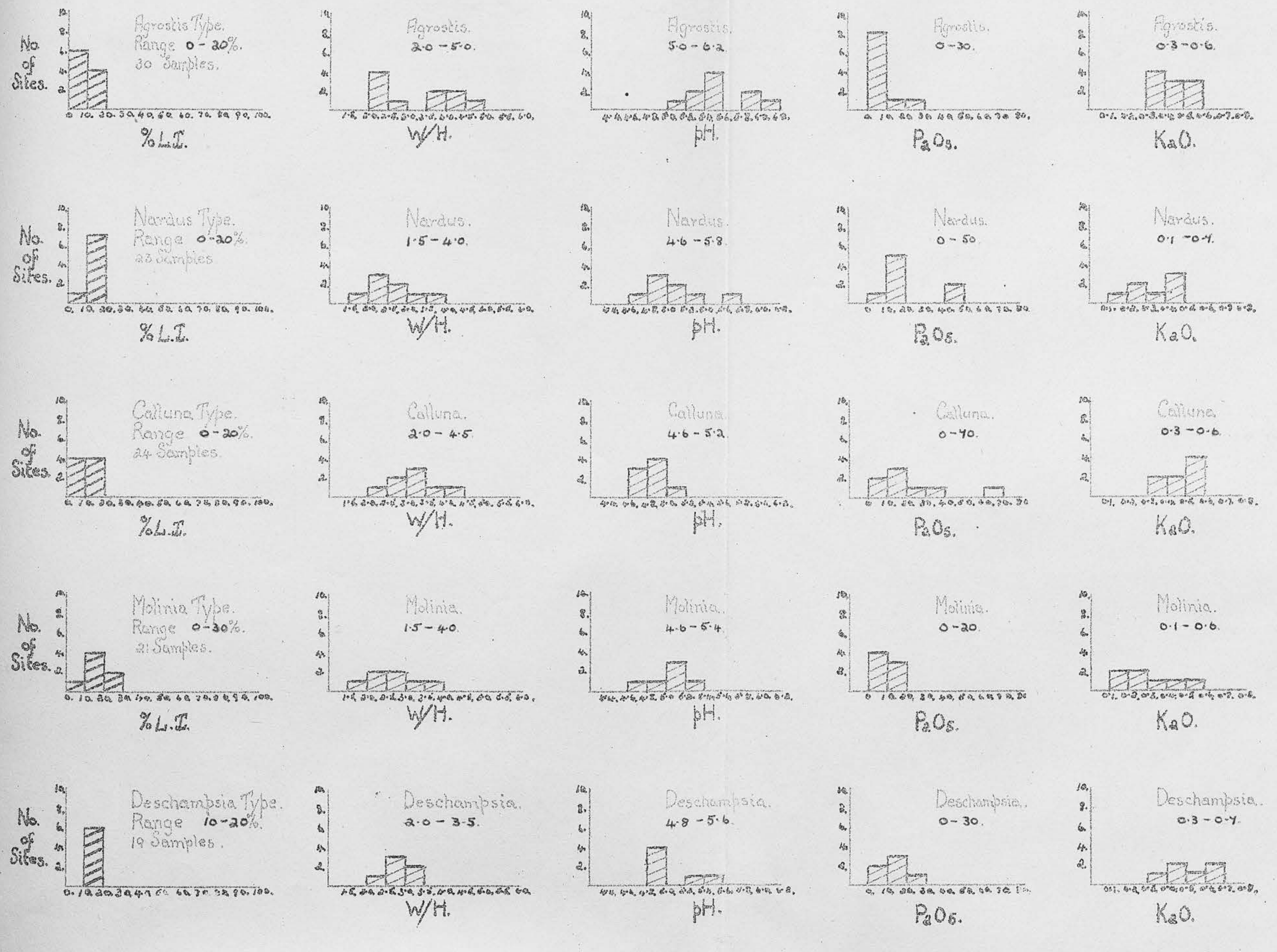
The subsoils show a similar Loss on Ignition range. The Water/Humus results for the subsoils are usually higher than those for the corresponding topsoil, though the subsoil and topsoil Water/Humus ranges are essentially the same. The subsoils are typically less acid than the topsoils, a condition particularly well illustrated by the Calluna vegetation type. Phosphates, though normally /

normally showing little change between topsoils and subsoils, give exceptionally high results in certain sites in the Calluna and Nardus vegetation types. Available potassium is low in the subsoils in contrast to the high values typical of the topsoils.

TOPSOILS.


No. of Sites.
Agrostis Type. Range 10–40% 110 Samples.
% L.I.
Agrostis. 1·0. – 5·0.
W/H.
Agrostis. 4·8 – 5·8.
pH.
Agrostis. 3 – 9.
P_2O_5.
Agrostis. 0·5 – 0·8.
K_2O.
Nardus Type. Range 10–100%. 101 Samples.
Nardus. 1·0 – 4·0.
Nardus. 3·8 – 6·8.
Nardus. 3 – 15.
Nardus 0·4 – 1·0.
Calluna. Type. Range 10 – 100% 100 Samples.
Calluna. 2·6 – 4·5.
Calluna. 3·6 – 4·2.
Calluna. 3 – 11.
Calluna. 0·7 – 1·1.
Molinia Type. Range 40–90%. 70 Samples.
Molinia. 2·0 – 4·0.
Molinia. 4·0 – 4·6.
Molinia. 3 – 17.
Molinia. 0·4 – 0·9.
Deschampsia Type. Range 10–40%. 61 Samples.
Deschampsia. 0·5 – 3·0.
Deschampsia. 4·2 – 5·0.
Deschampsia. 5 – 19.
Deschampsia. 0·6 – 0·9.

SUBSOILS.


No. of Sites.
Agrostis Type.
Range 0 - 20%.
30 Samples.
%L.I.
Agrostis.
2.0 - 5.0.
W/H.
Agrostis.
5.0 - 6.2.
pH.
Agrostis.
0 - 30.
P_2O_5.
Agrostis.
0.3 - 0.6.
K_2O.
Nardus Type.
Range 0 - 20%.
23 Samples.
%L.I.
Nardus.
1.5 - 4.0.
W/H.
Nardus.
4.6 - 5.8.
pH.
Nardus.
0 - 50.
P_2O_5.
Nardus.
0.1 - 0.4.
K_2O.
Calluna Type.
Range 0 - 20%.
24 Samples.
%L.I.
Calluna.
2.0 - 4.5.
W/H.
Calluna.
4.6 - 5.2.
pH.
Calluna.
0 - 40.
P_2O_5.
Calluna.
0.3 - 0.6.
K_2O.
Molinia Type.
Range 0 - 30%.
21 Samples.
%L.I.
Molinia.
1.5 - 4.0.
W/H.
Molinia.
4.6 - 5.4.
pH.
Molinia.
0 - 20.
P_2O_5.
Molinia.
0.1 - 0.6.
K_2O.
Deschampsia Type.
Range 10 - 20%.
19 Samples.
%L.I.
Deschampsia.
2.0 - 3.5.
W/H.
Deschampsia.
4.8 - 5.6.
pH.
Deschampsia.
0 - 30.
P_2O_5.
Deschampsia.
0.3 - 0.4.
K_2O.

SECTION 6

INTER-RELATION OF SOIL FACTORS

INTERRELATIONS OF TOPSOIL LOSS ON IGNITION WATER/HUMUS, pH AND EXCHANGEABLE CALCIUM IRRESPECTIVE OF VEGETATION TYPE

1. In this sub-section the interrelations of the principal soil factors, Loss on Ignition, pH, and Water/Humus are discussed. No relationship was found between pH and the W/H ratio.

<u>Loss on Ignition/pH</u>:-

In Graph 2, page 203, the relationship between L.I. and pH is shown. Each point plotted represents the mean pH and L.I. percentage for each of the 46 sites investigated - in all 443 samples.

From the following data the Correlation Coefficient r is calculated.

$$n = 46$$

Sum of Squares L.I. = 37,474

" " " pH = 12.89

Sum of Products = - 456.6

$$\text{Correlation Coefficient } r = \frac{\Sigma d_1 \times d_2}{\sqrt{S.S.d_1^2 \times S.S.d_2^2}}$$

$$= \frac{-456.6}{695.0}$$

$$r = \underline{\underline{-0.657}}$$

$$t = \frac{r \times \sqrt{n-2}}{\sqrt{1-r^2}}$$

$$= \frac{4.36}{0.754}$$

GRAPH 2.
% L.I.
pH.
0.
10.
20.
30.
40.
50.
60.
70.
80.
90.
3·5.
3·6.
3·7.
3·8.
3·9.
4·0
4·1.
4·2.
4·3.
4·4.
4·5
4·6
4·7.
4·8
4·9.
5·0
5·1
5·2
5·3.
5·4
5·5
5·6
5·7.
5·8.
5·9.

$$t = \underline{\underline{5.78}}$$

At the 0.01 level of significance with 44 degrees of freedom (n - 2), t from the tables equals 2.576. The value of t calculated in this correlation equals 5.78, therefore there is a significant negative correlation between pH and L.I. percentage. This indicates that a low pH is found on Sourhope where the L.I. percentage is high, and vice versa.

<u>Loss on Ignition / Water/Humus Ratio</u>:-

In Graph 3, page 205, the relationship between L.I. and W/H in 46 sites is shown. The results are the means of 443 topsoil samples.

The Correlation Coefficient r is calculated from the following data:-

n = 46

Sum of Squares L.I. = 37,474

" " " W/H = 56.10

Sum of Products = 742.70

$$\text{Correlation Coefficient } r = \frac{\Sigma d_1 \times d_2}{\sqrt{S.S.d_1^2 \times S.S.d_2^2}}$$

$$= \frac{+\ 742.70}{1450.0}$$

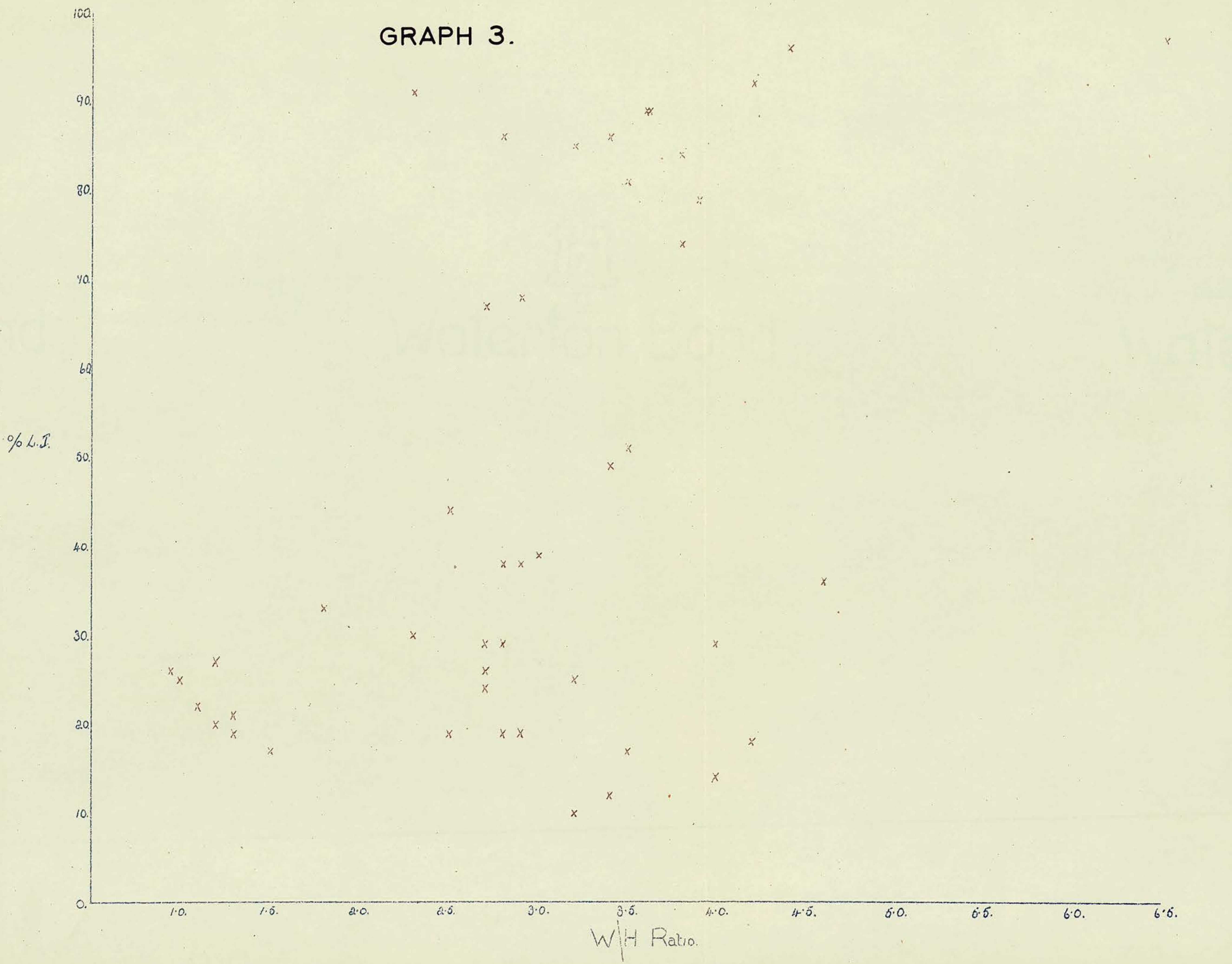
$$= \underline{\underline{+\ 0.512}}$$

$$t = \frac{r \times \sqrt{n - 2}}{\sqrt{1 - r^2}}$$

$$= +\ \frac{3.40}{0.859}$$

$$= \underline{\underline{+\ 3.96}}$$

GRAPH 3.



100
90
80
70
60
50
40
30
20
10
0
% L.I.
1·0.
1·5.
2·0.
2·5.
3·0.
3·5.
4·0.
4·5.
5·0.
5·5.
6·0.
6·5.
W/H Ratio.

At the 0.01 level of significance with 44 degrees of freedom (n - 2), t from the tables equals 2.576. The value of t in this correlation is 3.96, thus there is a significant positive correlation between W/H and L.I. percentage. This indicates that the amount of water held per part of humus (W/H) increases as the L.I. percentage increases.

Exchangeable Calcium/pH:-

2. In this sub-section the relationship between percentage exchangeable calcium and pH is shown. The results are grouped in pH units of 0.1, and Graph 4 shows the distribution of the mean results for exchangeable calcium between pH 4.0 - 5.0. As formerly noted on page 177 when dealing with the relations of the major vegetation types to percentage exchangeable calcium, the results obtained from the topsoils are most easily compared when they are expressed in terms of base saturation. This obviates the error in the analytical process caused by the varying amounts of organic material.

In Graph 4, page 210, $\frac{\text{Ex. Calcium \% x 1000}}{\text{\% L.I.}}$ is plotted against pH, and from the following data the Correlation Coefficient r is calculated. The other correlation coefficients determined in this thesis are calculated by exactly the same method as this, and have therefore not been written out in full (See Table 13.).

TABLE 13.

Ex.Ca. x 1000 / % L.I.	Diff. from Mean (d)	$(d)^2$	pH	Diff. from Mean (d_1)	$(d_1)^2$	$d \times d_1$
0.66	- 0.67	0.449	4.0	- 0.5	0.25	+ 0.335
0.88	- 0.45	0.203	4.1	- 0.4	0.16	+ 0.180
0.99	- 0.34	0.116	4.2	- 0.3	0.09	+ 0.102
0.99	- 0.34	0.116	4.3	- 0.2	0.04	+ 0.068
1.07	- 0.26	0.068	4.4	- 0.1	0.01	+ 0.026
1.25	- 0.08	0.006	4.5	0	0	-
1.38	+ 0.05	0.003	4.6	+ 0.1	0.01	+ 0.005
1.47	+ 0.14	0.020	4.7	+ 0.2	0.04	+ 0.028
1.86	+ 0.53	0.281	4.8	+ 0.3	0.09	+ 0.159
2.02	+ 0.69	0.476	4.9	+ 0.4	0.16	+ 0.276
2.02	+ 0.69	0.476	5.0	+ 0.5	0.25	+ 0.345
TOTAL 14.59	S.S.:	2.214	49.5	S.S.:	1.10	+ 1.524
Mean 1.33			4.5			

$$\text{Correlation Coefficient } r = \frac{\text{Total } \Sigma d \times d_1}{\sqrt{S.S.d^2 \times S.S.d_1^2}}$$

$$= + \frac{1.524}{1.562}$$

$$= + 0.976$$

This result for r indicates a very high positive correlation between "base saturation" and pH between pH 4.0 - 5.0. The result is highly significant at the 0.01 level.

On the same Graph 4, the relationship of pH to Percentage Exchangeable Calcium x 1000, between pH 4.0 - 5.0, is shown. The Correlation Coefficient r is calculated from the following data:-

$$n = 11$$

$$\text{Sum of Squares \% Ex.Ca. x 1000} = 822$$

$$\text{" " " pH} = 1.10$$

$$\text{Sum of Products} = -\ 22.5$$

$$\text{Correlation Coefficient } r = \frac{\Sigma d_1 \times \Sigma d_2}{\sqrt{S.S.d_1^2 \times S.S.d_2^2}}$$

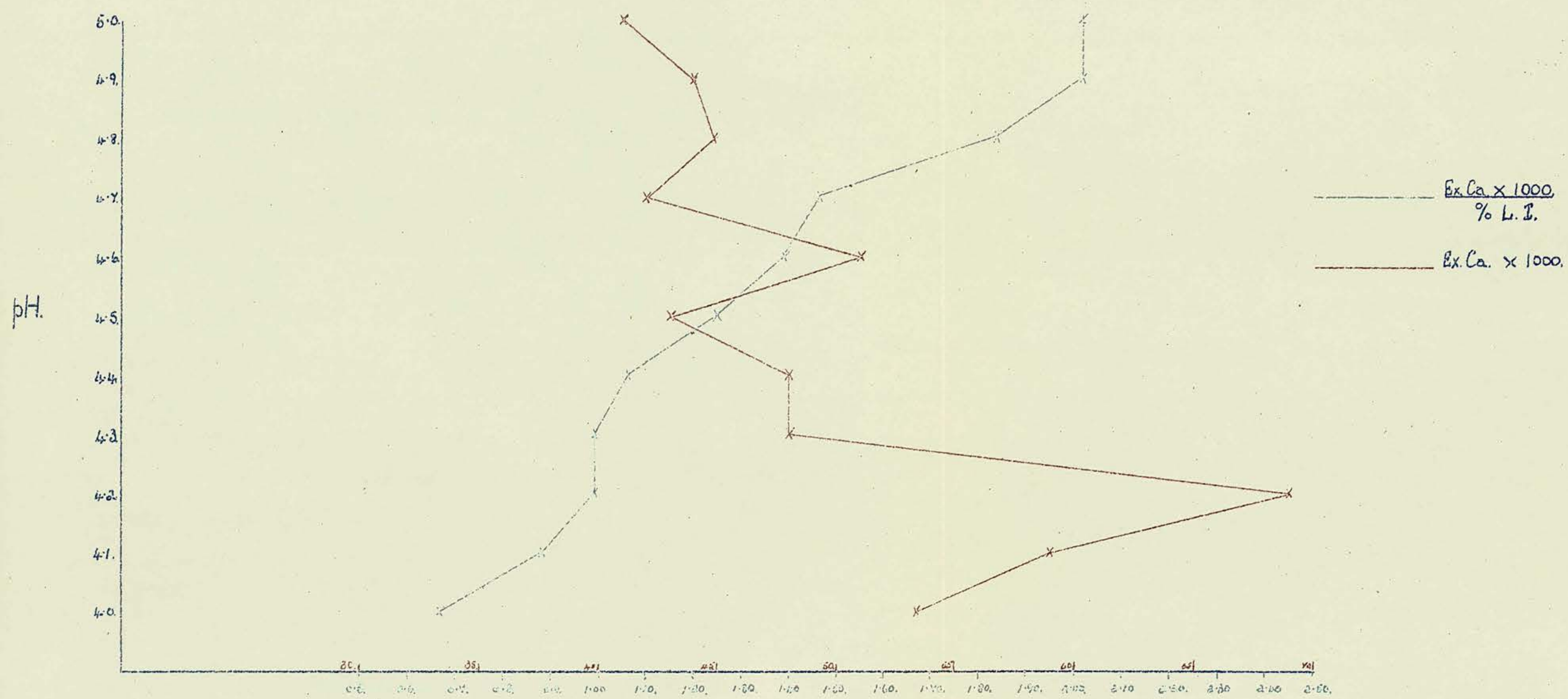
$$= -\frac{22.5}{30.06}$$

$$= \underline{\underline{-\ 0.749}}$$

This result indicates that there is a significant negative correlation between percentage exchangeable calcium and pH, from pH 4.0 - 5.0, at the 0.01% level.

These graphs show that in hill soils between pH 4.0 - 5.0 where, by arable standards, the L.I. percentage is high, the percentage of exchangeable calcium, as estimated by the writer, increases as the soil becomes more acid (negative correlation). When, however, the results are expressed in terms of "base saturation", the relationship between pH and the degree of base saturation shows that, as the soil becomes less acid, the degree of base saturation increases (a positive correlation).

GRAPH 4.



STATISTICAL TREATMENT OF pH AND WATER/HUMUS RATIO RESULTS FOR THE EIGHT MAIN VEGETATION TYPES.

In Table 14 and 15, page 213 and 214, the sum of the variates, the number of variates, the mean, the sum of squares of the difference, the Standard Deviation and Standard Error of the mean are shown for each of the eight principal vegetation types, for pH and W/H.

Using the Standard Error results the standard error of the difference (E_D) of the means was calculated i.e.

$$E_D = \sqrt{E_A + E_B}$$

In the book "Statistical Technique in Agricultural Research" by Paterson, it is shown that, where E_D is the error of the difference and D is the difference between the two means, when $\frac{D}{E_D}$ is greater than 2.0 the difference between the two means will be significant at the 0.05 level.

In Tables 16 and 17 the values for $\frac{D}{E_D}$ are shown for pH and the W/H ratio for the eight vegetation types. From the magnitude of the figures it can be seen that the majority of the results indicate a highly significant difference between the means even at the 0.01 level (i.e. $\frac{D}{E_D}$ is greater than 2.6).

In Table 16 - pH - only one difference, that between Agrostis 1 and Nardus 1, is not significant at the 0.05 level. At the 0.01 level the difference between Nardus 1 and Deschampsia flexuosa is just significant.

In Table 17 - W/H - again only one value of $\frac{D}{E_D}$ is not significant at the 0.05 level, that between Nardus 2 and Molinia. At the 0.01 level the differences in the means of Calluna 2 and Molinia, and Calluna 2 and Nardus 1 are non-significant.

These tables indicate that, on Sourhope, there is a significant difference between the means of the various vegetation types investigated for acidity and Water/Humus ratio. At the 0.05 level one ratio from each table is non-significant.

TABLE 14

STANDARD DEVIATION AND STANDARD ERROR OF THE MEAN OF EIGHT VEGETATION TYPES - WATER/HUMUS RATIO (TOPSOILS)

Nardus Type 1

y = 134.0
n = 56
Mean = 2.39
S.S. = 39.40
S.D. = 0.85
S.E. = 0.114

Nardus Type 2

y = 149.0
n = 45
Mean = 3.31
S.S. = 28.70
S.D. = 0.81
S.E. = 0.121

Agrostis Type 1

y = 97.1
n = 50
Mean = 1.94
S.S. = 31.43
S.D. = 0.80
S.E. = 0.113

Agrostis Type 2

y = 234.0
n = 60
Mean = 3.90
S.S. = 20.88
S.D. = 0.59
S.E. = 0.076

Calluna Type 1

y = 187.1
n = 40
Mean = 4.68
S.S. = 66.87
S.D. = 1.29
S.E. = 0.204

Calluna Type 2

y = 180.4
n = 60
Mean = 3.01
S.S. = 8.18
S.D. = 0.37
S.E. = 0.048

Deschampsia

y = 90.2
n = 61
Mean = 1.48
S.S. = 33.44
S.D. = 0.74
S.E. = 0.095

Molinia

y = 228.8
n = 71
Mean = 3.22
S.S. = 27.05
S.D. = 0.65
S.E. = 0.074

TABLE 15

STANDARD DEVIATION AND STANDARD ERROR OF THE MEAN OF EIGHT VEGETATION TYPES - pH (TOPSOILS)

	Nardus Type 1	Nardus Type 2	Agrostis Type 1	Agrostis Type 2	Calluna Type 1	Calluna Type 2	Deschampsia	Molinia
y	268.0	188.4	243.1	321.4	149.5	233.4	280.5	307.8
n	56	45	50	60	40	60	61	71
Mean	4.79	4.19	4.86	5.36	3.74	3.89	4.60	4.34
S.S.	13.0	3.1	4.1	4.50	1.38	2.5	4.51	1.91
S.D.	0.49	0.27	0.29	0.28	0.19	0.20	0.27	0.16
S.E.	0.065	0.040	0.041	0.036	0.030	0.026	0.035	0.019

TABLE 16

Values of $\frac{D}{E_D}$ for pH

	Mc	Df	Ag 1	Ag 2	Ns 1	Ns 2	Cv 1
Df	4.00	-	-	-	-	-	-
Ag 1	11.55	4.81	-	-	-	-	-
Ag 2	24.7	15.20	9.10	-	-	-	-
Ns 1	6.60	2.60	0.90	7.70	-	-	-
Ns 2	3.36	7.74	11.60	21.70	10.80	-	-
Cv 1	16.60	18.70	22.00	34.50	14.70	9.00	-
Cv 2	13.60	16.10	19.80	32.90	12.90	6.25	3.75

TABLE 17.

Values of $\frac{D}{E_D}$ for W/H

	Mc	Df	Ag 1	Ag 2	Ns 1	Ns 2	Cv 1
Df	14.30	-	-	-	-	-	-
Ag 1	9.20	3.01	-	-	-	-	-
Ag 2	6.05	19.80	14.20	-	-	-	-
Ns 1	6.02	6.13	2.80	11.00	-	-	-
Ns 2	0.62	11.80	8.20	4.21	5.50	-	-
Cv 1	6.67	14.20	11.70	3.60	5.74	9.76	-
Cv 2	2.35	14.60	8.74	10.00	2.31	5.10	7.96

Df = Deschampsia flexuosa Type
Mc = Molinia caerulea "
Ag 1 = Non-gleyed Agrostis "
Ag 2 = Gleyed Agrostis "
Ns 1 = Nardus stricta ("Mineral") Type
Ns 2 = Nardus stricta ("Organic") "
Cv 1 = Calluna vulgaris ("Organic") "
Cv 2 = Calluna vulgaris ("Mineral") "

A COMPARISON OF THE pH'S OF SOILS ESTIMATED WHEN WET AND AFTER BEING AIR-DRIED

Although all the pH results used in this thesis are for air-dry soils, it was considered that a comparison of pH's taken while the soil was still wet and after air drying would be of interest. Facilities for estimating pH were not available in the farm laboratory, but arrangements were made to have a certain number of the soils transported to Edinburgh, where the wet pH's were determined. The pH was estimated "wet" within a week of taking the sample in the field - the samples were stored and transported in waterproof lined bags.

In Appendix III will be seen the wet and air-dry pH's for 145 soil samples. Generally the topsoil pH falls 0.2 - 0.3 units on air-drying. In Sites 51, 59 and 63, however, - soils of the Brown Earth and Gley types - the topsoil variation in pH is much larger. In one sample the pH falls 0.8 on air-drying. With the exception of the three sites already mentioned, the subsoils show little change in pH on air-drying; in a few cases the pH of the air-dry sample is slightly less acid than that of the wet sample.

SECTION 7

RELATION OF PRINCIPAL SPECIES TO SOIL CONDITIONS

THE RELATION BETWEEN THE PRINCIPAL SPECIES OCCURRING ON SOURHOPE AND THE SOIL TYPE AND CONDITIONS

In this section the general distribution of the main plant species found on Sourhope will be discussed. This will be done in two parts. The first part is concerned with the occurrence of these species in the different vegetation types, the second with the distribution of the species in relation to soil conditions.

Part I.

In Table 18 the distribution of seventeen hill species with regard to their presence or absence in the eight main vegetation types already identified, is shown. A single cross indicates that the species has a Specific Frequency of 20% or over, a double cross that the species is dominant, and a line that the species is absent. As this paper deals with general trends, it was decided that the inclusion of species of very low Specific Frequency (5 - 15%) in this section would only confuse the overall distribution picture. Also, as has already been shown, the error in the method of vegetation analysis at these low frequencies is high.

The Table has been divided into three groups. The first group includes species occurring only on "organic" soils; the second species confined to "mineral" soils; the third species occurring /

occurring on both "mineral" and "organic" soils.

Group 1, composed of Molinia caerulea, Eriophorum vaginatum, Juncus squarrosus, Erica tetralix and Scirpus caespitosus, all occur on peat or thick mor humus. They are confined to three of the main vegetation types investigated, namely, the "organic" sub-types of Nardus and Calluna, and to the Molinia type. Juncus squarrosus is common to all three, Scirpus to the Calluna and Molinia types, and Erica tetralix and Eriophorum vaginatum to the Calluna type only. Molinia, which is the dominant species in one of the principal vegetation types investigated, occurs as a subsidiary species in the "organic" Nardus type.

Group 2, occurring only on a "mineral" soil where a thin sub-litter mor humus layer may or may not be present, is composed of Trifolium repens, Poa pratensis, Festuca rubra, Holcus mollis and Deschampsia caespitosa. These species are present in four of the main vegetation types, i.e. the "mineral" Nardus soil, the two Agrostis types and the Deschampsia flexuosa type. Holcus mollis is the only species of the five occurring in all four soil types. Poa pratensis and Festuca rubra are both represented in the two Agrostis communities, the former species being also found in the Deschampsia flexuosa and the latter in the "mineral" Nardus type. Deschampsia caespitosa is found only in the two Agrostis types. /

types. Trifolium repens has the most restricted distribution of all the species in this group. It is confined to the gleyed Agrostis type, though the Table shows it is also present in the "mineral" Nardus type. This is confined to a single site (Site 38). This site, as has already been noted, though having a dominantly Nardus stricta vegetation, has subordinate species and soil profile and conditions which identify it with the gleyed Agrostis community.

Group 3 comprises ten species - Calluna vulgaris, Nardus stricta, Agrostis spp., Festuca ovina, Deschampsia flexuosa, Anthoxanthum odoratum, Vaccinium myrtillus, Potentilla erecta, Galium saxatile and Luzula campestris. These species occur on both "mineral" and "organic" soils, as is clearly shown in the Table. Deschampsia flexuosa is most widely distributed, being present in seven out of the eight vegetation types. Agrostis spp., Festuca ovina, Anthoxanthum odoratum and Luzula campestris have a similar distribution, being found in all the vegetation types with the exception of those dominated by Calluna vulgaris. Nardus is not shown to be present in the "mineral" Calluna or Deschampsia flexuosa types, though, as previously stated, this species was purposely avoided in the selection of these sites. From what has been already concluded concerning the wide tolerance of soil conditions /

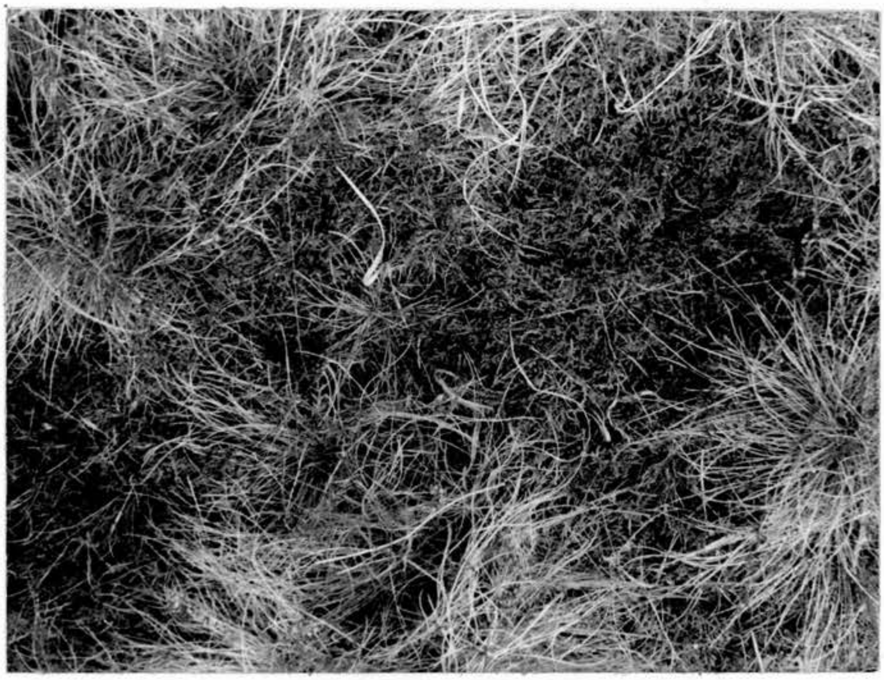


Photo. 20. (Site 43)

Nardus stricta tussocks in a burned Callunetum. The Calluna is regenerating but is very short.

conditions exhibited by Nardus, it seems justifiable to include Nardus as a species which will be commonly found in any of the eight major vegetation types and sub-types. Vaccinium myrtillus is also widely distributed, occurring in all but the two Agrostis types. Potentilla erecta and Galium saxatile have essentially the same distribution, Potentilla, however, not being represented in the "organic" Nardus soil. Calluna vulgaris has the most limited distribution, always occurring in a dominant or co-dominant role. As has been previously suggested, Calluna's presence in the "organic" Nardus soils indicates an area of heather invaded by Nardus. Depending on future management, the species most favoured will eventually become dominant (see Photo 20, page 221).

TABLE 18.

THE DISTRIBUTION OF TWENTY PRINCIPAL SPECIES IN EIGHT MAIN VEGETATION TYPES

Species	Mineral Nardus 1	Organic Nardus 2	Organic Calluna 1	Mineral Calluna 2	Non-Gley Agrostis 1	Gley Agrostis 2	Molinia	Deschampsia
Group 1. - "Organic" Soil Species								
Molinia caerulea ..	-	+	-	-	-	-	++	-
Eriophorum vaginatum	-	-	+	-	-	-	-	-
Juncus squarrosus ..	-	+	+	-	-	-	+	-
Erica tetralix	-	-	+	-	-	-	-	-
Scirpus caespitosus ..	-	-	+	-	-	-	+	-
Group 2. - "Mineral" Soil Species								
Trifolium repens ..	+	-	-	-	-	+	-	-
Poa pratensis	-	-	-	-	+	+	-	+
Festuca rubra	+	-	-	-	+	+	-	-
Holcus mollis	+	-	-	-	+	+	-	+
Deschampsia caespitosa	-	-	-	-	+	++	-	-
Group 3. - "Mineral" and "Organic" Soil Species								
Nardus stricta	++	++	+	-	+	+	+	-
Calluna vulgaris ..	-	+	++	++	-	-	-	-
Agrostis spp.	+	+	-	-	++	++	+	+
Festuca ovina	+	+	-	-	+	+	+	+
Deschampsia flexuosa .	+	+	+	+	+	-	+	++
Anthoxanthum odoratum	+	+	-	-	+	+	+	+
Vaccinium myrtillus ..	+	+	+	+	-	-	+	+
Potentilla erecta ..	+	-	-	-	+	-	+	+
Galium saxatile.. ..	+	+	-	-	+	-	+	+
Luzula campestris ..	+	+	-	-	+	+	+	+

- Absent.

++ - Dominant Species.

\+ Present over 20% Specific Frequency.

Distribution of 20 Principal Species with Relation to Soil Conditions.

Part II.

In Table 19 (p.229) the range figures for each species for Loss on Ignition, Water/Humus Ratio and pH are shown. The species have been grouped with reference to L.I. figures and fall into the three main categories distinguished for Table i.e. "organic" soil species, "mineral" soil species and species occurring in both soil types. Table shows the complete range for each of L.I., W/H. and pH. The range figures are obtained from the mean soil factor results for each site in which the species is present with a specific frequency of over 20%. Range figures for available potassium and phosphates, which are shown for each main vegetation type in Section 4, are not included in this Table. It is considered that they are of little value as a means of comparing or contrasting the different habitats colonised by these species.

Group 1:

This is formed of five species already detailed in the first part of this section. The L.I. results are closely comparable though Eriophorum vaginatum and Erica tetralix appear to prefer a purer form of humus than that colonised by the other three species. The preference of these species for the purer humus type is reflected in the very high W/H range (4.2 - 6.6) and the /

the high acidity of the soils (pH 3.6 - 3.9). Scirpus caespitosus, occurring within a limited but drier W/H range of 3.9 - 4.4 shows a wider pH range of from pH 3.6 - 4.3. Juncus squarrosus colonises soils which, though still very acid (pH 3.8 - 4.3), are drier than those found under the previous three species (W/H 3.2 - 3.8). The least acid range in this group is possessed by Molinia caerulea (pH 4.2 - 4.5). This species also occurs on relatively drier soils (W/H 2.5 - 3.9). Reviewing the group generally it appears that species which are confined to highly organic soils are those which can tolerate a high water content in the soil and a high degree of acidity.

Group 2:

This group embraces five species already detailed in the first part of this section. The Loss on Ignition results indicate that these species are confined to the "mineral" soil type. Poa pratensis, Holcus mollis, Festuca rubra and Deschampsia caespitosa show a similar range of W/H ratio. Trifolium repens has a much more limited range of W/H than the previous four species. It appears to prefer soils which are "wet", but not extremely wet, as is typical of those sites where the percentage of Deschampsia caespitosa is very high. A comparable range of Loss on Ignition results is exhibited by all the species in this group /

group with the exception of Trifolium repens. The L.I. results for this species show that it colonises soils of "relatively" low organic matter (10-17% L.I.). Poa pratensis, Festuca rubra and Holcus mollis are all found on soils of a similar acidity range - approximately pH 4.4 - 5.7. They can thus tolerate a greater degree of acidity than Deschampsia caespitosa (4.9 - 5.7) and Trifolium repens (5.4 - 5.7). The very high, but narrow, pH range of white clover again sets this species apart from the other four in the group.

Reviewing Group 2 generally, the results indicate that the species composing it are found only on soils of the lower L.I. range. The W/H range is broad and acidity is low when considered in relation to the pH results of the other groups Wild white clover is particularly interesting, the figures obtained showing that, on Sourhope, it colonises a very restricted soil type.

<u>Group 3</u>:

Ten species compose this group. They occur on both "mineral" and "organic" soils, the list of species and range of figures for each species being shown in Table 19 (p.229.). As the species are found in both soil categories, the L.I. range is broad and only small variations are shown by the various species. Calluna vulgaris, however, ranging /

ranging from 25.0 - 97.0% L.I. does suggest that it prefers a more humose soil and that, particularly at the lower end of its occurrence with reference to L.I., it is not found on soils of low organic content. The range of the W/H ratio is also closely comparable, Calluna being the only exception. Calluna is confined to the wetter range of soils, the lowest mean ratio estimated being 2.7. In contrast to the constancy of the results for L.I. and W/H found in this group, pH shows a more diverse range. Nardus, Agrostis, Deschampsia flexuosa, Anthoxanthum odoratum and Luzula campestris indicate a very wide acidity range, including those of all the main vegetation types investigated. Festuca ovina and Potentilla erecta are found where the acidity is less extreme (the lowest pH results for these two species is 4.2). Galium saxatile (pH 3.8 - 5.1) does not commonly occur on the soils of highest or lowest acidity on Sourhope. The most acid ranges are exhibited by Vaccinium myrtillus (3.8 - 4.6) and Calluna vulgaris (3.6 - 4.1).

The trends illustrated by this group are principally brought out by the pH ranges. With the exception of Calluna, L.I. and W/H figures are essentially similar. The pH range figures, on the other hand, indicate that, while some of the species may colonise soils of very varying acidities, others show more specific /

specific range, which may play some part in determining whether a species will be present in a plant community. The figures in Table are of interest as a means of comparing the soil conditions found under Potentilla erecta and Galium saxatile. These species have a wide distribution. The figures indicate that water conditions are essentially the same for each. Galium, however, shows a preference for more organic and more acid soils than Potentilla.

Owing to its limited distribution on Sourhope Vaccinium myrtillus communities were not included in the major vegetation types investigated in the course of this work. Site 49 on the Banks, however, which is co-dominant Vaccinium-Nardus, was sampled and gave the following results.

Vegetation Analysis:

Vm	Ns	Df	Fo	Gs	Pe	Ao	Ls
100	85	60	5	15	15	5	15

Soil Analysis:

n	L.I.	W/H	pH	P_2O_5	K_2O
10	18.0	2.45	4.2	3.0	0.55

Reviewing both parts of this section, it is evident that the more important hill species can be divided into three main groups with reference to their L.I. range. These groups have definite trends with relation to the W/H ratio and pH. Within each group the range figures for each soil factor tend to be similar though certain species exhibit narrower zones.

TABLE 19.

THE DISTRIBUTION OF THE TWENTY PRINCIPAL HILL SPECIES

WITH RELATION TO L.I.%, W/H AND pH RANGE

Species	Loss on Ignition	Water/Humus	pH	No. of Samples
	Group 1. - "Organic" Soil Species			
Molinia caerulea	44.0 - 89.0	2.5 - 3.9	4.2 - 4.5	81
Eriophorum vaginatum	From 97.0	4.4 - 6.6	3.6 - 3.9	20
Juncus squarrosus..	81.0 - 89.0	3.2 - 3.8	3.8 - 4.3	41
Erica tetralix	92.0 - 97.0	4.2 - 6.6	3.6 - 3.9	30
Scirpus caespitosus	78.0 - 97.0	3.9 - 4.4	3.6 - 4.3	30
	Group 2. - "Mineral" Soil Species			
Trifolium repens	10.0 - 17.0	3.2 - 4.0	5.4 - 5.7	30
Poa pratensis	10.0 - 29.0	1.0 - 4.6	4.6 - 5.6	80
Festuca rubra	10.0 - 36.0	1.3 - 4.6	4.4 - 5.7	100
Holcus mollis	10.0 - 36.0	1.1 - 4.6	4.5 - 5.7	110
Deschampsia caespitosa	10.0 - 36.0	1.2 - 4.6	4.9 - 5.7	90
	Group 3. - "Mineral" and "Organic" Soil Species			
Nardus stricta	12.0 - 92.0	1.2 - 3.8	3.7 - 5.7	192
Calluna vulgaris	25.0 - 97.0	2.7 - 6.6	3.6 - 4.1	110
Agrostis spp.	10.0 - 91.0	0.9 - 4.6	3.9 - 5.7	283
Festuca ovina	10.0 - 91.0	0.9 - 3.8	4.2 - 5.4	230
Deschampsia flexuosa	12.0 - 91.0	0.9 - 3.9	3.9 - 5.6	293
Anthoxanthum odoratum	10.0 - 91.0	0.9 - 4.6	3.9 - 5.6	176
Vaccinium myrtillus	19.0 - 91.0	0.9 - 3.9	3.8 - 4.6	132
Potentilla erecta	12.0 - 86.0	0.9 - 3.4	4.2 - 5.6	150
Galium saxatile	17.0 - 91.0	0.9 - 3.8	3.8 - 5.1	192
Luzula campestris	10.0 - 89.0	0.9 - 3.9	3.9 - 5.6	127

SECTION 8

CONCLUSIONS

CONCLUSIONS.

The conclusions and trends deriving from the fore-going sections are discussed under the following headings:-

a) A comparison of the writer's findings with the findings of others as they apply to the soil conditions which support the principal hill vegetation types.

b) The relative importance of the various soil factors differentiating the five vegetation types investigated.

c) The advantages and disadvantages of the writer's methods of soil analyses.

d) The bearing of the writer's findings on the extent to which the edaphic factor controls the distribution of the five hill vegetation types in S.E. Scotland.

a.) This Section contains a brief summary of the findings of the writer which are in general agreement with those of other investigators. Differences, where they exist, are in detail rather than in principle, and appaer to be justified in the light of the results from the foregoing Sections. A full literature review will be found in Section 1.

Agrostis-Fescue Type:

The findings are confirmed of Heddle and Ogg (2), 1933 and (3) 1936, and of Pearsall (1) 1950, which agree that Trifolium repens is associated with a high percentage of exchangeable calcium and intense flushing. Heddle and Ogg also found that in this vegetation type, phosphates were low and potassium was high; the writer's results confirm this though his figures for potassium are relatively lower when compared with those of the other vegetation types investigated. The writer's pH range for both subtypes (4.8 - 5.6) tends to be higher and narrower than those recorded by others. Pearsall (1) 1950, is of the opinion that Agrostis-fescue is associated with more or less acid, base deficient soils of the Brown-earth type. This is borne out by the writer's findings as was also the increase in Deschampsia caespitosa and Holcus spp. where flushing was active. Where, however, Deschampsia caespitosa was common, the soil type was found to be of the Gley rather than of the Brown-earth type.

Calluna vulgaris Type:

Many writers including Adamson (4) 1918, Pearsall (5) 1938, Woodhead (6) 1906, Fritsch and Salisbury (7) 1915, Elgee (8) 1915, and Lewis (9) 1904, comment on the peat thickness and peat type found under this vegetation. The two sub-types distinguished by the writer correspond generally to the "Calluna Heath" and "Calluna Moor" of the others. In agreement with Elgee (8) 1915 and Lewis (9) 1904, the 'mineral' or 'heath' type was found to be drier than the 'organic' or moor Callunetum. Both sub-types were 'wetter' than the Nardus types, as was found by Jeffreys (10) 1917.

The writer's pH range of 3.6 - 4.1 for both sub-types compares well with the findings of others. Klapp (11) 1951, however, states that there is no difference between the acidity of ~~Cal~~Calluna and Nardus land. In this case, the writer's results show a significant difference.

Nardus stricta Type:

Two types of Nardus vegetation are distinguished by the writer. The soils showed a wide range of acidity, and a layer of mor humus or peat was always present. Bases are low. This agrees with the views of Pearsall (1) 1950, though the 'mineral' type of Callunetum is "wetter" than the 'mineral' type of Nardus and compares well with the "wetness" range exhibited by the 'organic' Nardus type. The pH range (3.9 - 5.1) agrees with that found by others.

others. The W/H ratio of 1.2 to 3.8 indicates that this species has a wide tolerance of "wetness. Available potassium is relatively high and phosphates is low.

Molinia caerulea Type.

This vegetation type is found on Sourhope on gentle slopes and where it would appear that lateral seepage is taking place. The peat is of the black amorphous type described by Fraser (13) 1933. The water status of the soil (2.5 - 4.0) found by the writer indicates that, with respect to "wetness", it compares closely with that of "mineral" Callunetum but is drier than the "organic" Callunetum. This agrees with the findings of Crump (15) 1911, but differs from those of Gorham (16) 1953, and Jeffreys (14) 1916. Jeffries (12) 1915, concluded that Molinia was dependent on a supply of relatively base-rich water. The writer's results do not confirm this, Calluna alone showing a lower base saturation. The very narrow pH limits found by the writer for this species compares well with those quoted by others.

Deschampsia flexuosa Type.

The occurrence of this vegetation type on the steep stony exposed brows of the hills where the soils are acid and low in bases, is in agreement with those described by many writers:- Tansley (17) 1949, Adamson (4) 1918, Jowett and Scurfield (18) 1949. The pH range, however, of 4.4 - 4.9 with a mean of 4.6 is generally higher than that quoted by Pearsall (1) 1950, Jowett and Scurfield (18)

Jowett and Scurfield (18) 1949, and Scurfield (19) 1953, Olsen (20) 1938, and Atkins and Fenton (21), 1930. It should be noted however, that some of these results refer to Deschampsia flexuosa occurring as ground flora of woodland where podsolization was active. No signs of active podsolization were found in the soils supporting this vegetation type at Sourhope. A thin mor humus layer was always present and available potassium and phosphates were both relatively high.

pH

A negative correlation was found by the writer between pH and Percentage Exchangeable Calcium. In agreement with Pearsall (22) 1952, pH was related to base saturation (See also Cooper (28) 1932), and acidity increased with an increase in organic matter percentage. No relation, however, was found between pH and "wetness". The findings of Jowett and Scurfield (23) 1952, with reference to the relations of organic matter, moisture and pH were also corroborated. With regard to the effect of drying on the pH of soils, the findings of the writer agree with those of Rost and Fieger (24) 1923 and Romell (25), 1932.

Exchangeable Calcium:

The writer's results showed that the percentage of exchangeable calcium in hill soils is usually below 0.1%. This bears out the findings of Ogg and Dow, (26) 1928, and Thomas (27) 1938. It was also shown that the varying amounts of exchangeable calcium

calcium played an important part in differentiating vegetation types as was found by Heddle and Ogg (2) 1933 and (37) 1936.

CONCLUSIONS (a)

LITERATURE REVIEW.

1.	Pearsall W.H.	1950	"Mountain & Moorlands" Collins.		
2.	Meddle & Ogg	1933	Scot. Jour. Agric.	Vol. 16	
3.	" "	1936	J. of Ecol.	Vol.24	p.220
4.	Adamson R.S.	1918	" " "	Vol. 6	p. 97
5.	Pearsall W.H.	1938	" " "	Vol.26	p.298
6.	Woodhead	1906	J. Lin. Soc. Bot.	Vol.37	p.333
7.	Fritsch & Salisbury	1915	New Phyt.	Vol.14	p.116
8.	Elgee F.	1914	J. of Ecol.	Vol. 2	p. 1
9.	Lewis F.J.	1904	Geog. Jour.	Vol.24	p.267
10.	Jeffreys H.	1917	J. of Ecol.	Vol. 5	p.129
11.	Klapp E.	1951	Zeit. Acker-u. Pflanz.	Vol.93	Ch. 4
12.	Jeffries T.A.	1915	J. of Ecol.	Vol. 3	p.93
13.	Fraser G.K.	1933	Forestry Bull.	No. 15	
14.	Jeffreys H.	1916	J. of Ecol.	Vol. 4	p.174
15.	Crump W.B.	1911	Rep. Brit. Assc. Portsmouth.		
16.	Gorham E.	1953	J. of Ecol.	Vol.41	p.153
17.	Tansley A.G.	1949	British Islands and their Vegetation Cambridge.		
18.	Jowett & Scurfield	1949	J. of Ecol.	Vol.37	p. 68
19.	Scurfield G.	1953	" " "	Vol.41	p. 1
20.	Olsen C.	1938	Comp. Rend. Lab. Carls.	Vol.22	p.405
21.	Atkins & Fenton	1930	Proc. Roy. Dub. Soc.	Vol.19	(N.S.)
22.	Pearsall W.H.	1952	J. Soil Sc.	Vol. 3	p. 41
23.	Jowett & Scurfield	1952	J. of Ecol.	Vol.40	p.393
24.	Rost & Fieger	1923	Soil Sc.	Vol.16	p.121
25.	Romell L.G.	1932	" "	Vol.34	p.161
26.	Ogg & Dow	1928	J. Agric. Sc.	Vol.18	p.131
27.	Thomas B.	1938	J. Min. Agric.	Vol.45	p.546
28.	Cooper H.P.	1932	Plant Phys.	Vol. 7	p.527

B. From the work carried out by the writer on Sourhope Farm the soil factors which proved most successful as a means of differentiating vegetation types were soil profile, Loss on Ignition, Water/Humus ratio, pH and Percentage exchangeable calcium. Available phosphates and potassium, though indicating certain trends, showed a wide variation even within the same site. The analytical methods used for these two factors, particularly those for available phosphates, are unreliable.

Soil profile is perhaps the most reliable indicator of soil conditions and it was on the basis of this factor that the Calluna, Nardus and Agrostis vegetation sub-types were distinguished. From the soil profile a fair estimate of soil-drainage conditions and of the degree of leaching can be made. In the writer's opinion these play the most important roles in differentiating hill vegetation type. pH, % Exchangeable calcium, and Loss on Ignition together indicate the degree of leaching in terms of acidity and base saturation. The Water/Humus ratio, where the clay percentage is low, gives results which allow a comparison of "wetness" under the various vegetation types. /

C. In the course of the analyses of the soils for the various soil factors, certain difficulties were encountered particularly with the highly organic soils. After air-drying, the "peaty" soils were exceedingly troublesome to sieve. It was found that the only satisfactory method was to rub the lumps through the sieve by hand - a time-consuming process. It was further found that the dry, finely sieved, organic-matter was not easily wetted as is necessary in the estimation of pH, available phosphates and potassium, and exchangeable calcium. Frequent stirring was required. Such organic soils were allowed to stand in contact with the distilled water, or Hydrochloric acid or Acetic acid for a longer time than that recommended ~~by~~ for the estimation method. In the available potassium estimation, no satisfactory method was found of preventing contamination of the mycelium by small pieces of organic material.

For estimating soil pH a Universal Indicator was tried in the farm laboratory. The results for mineral soils compared well with those obtained by using the Muirhead pH meter. In the highly organic soils, however, difficulty was found in comparing the colour produced with the standard colour - charts supplied. As the pH estimations using the Muirhead meter are on a volume /

volume basis, the results for both organic and mineral soils are comparable.

The method of phosphate analysis is complicated by the probable solubility of "unavailable" iron and aluminium phosphates. The pH of the extract using the Kirsanov method is low (tests showed it to be between pH 1.0 and 1.5).

The estimation of available phosphates and potassium and exchangeable calcium were all subgect to the effect on the analysis of the differing volumes of the soils. Expression of the percentage exchangeable calcium as base saturation counteracted the organic matter effect, but no relation was found between available phosphates or potassium with Loss on Ignition percentage. /

D. The findings in this thesis show, in the writer's opinion, that edaphic conditions do play a major role in the distribution of the vegetation types investigated. Each occurs within a fairly well defined range of soil conditions, particularly with reference to pH, base saturation and "wetness". Over the area investigated, the rain fall is generally constant and it appears likely that the main factors governing the vegetational distribution is the permeability of the soil and whether the soil water present is due to direct rainfall, or to lateral seepage, or to springs.

On the dry, permeable stony brows of the hills, or where the slope is very steep and the soil thin, the Deschampsia flexuosa type becomes dominant. Where the slope is less severe and where non base-rich lateral seepage from above takes place, Molinia caerulea is dominant. On the areas where flushing from springs enriches the soil, Agrostis becomes dominant. Where the drainage is impeded, Deschampsia caespitosa and Trifolium repens increase, the former species becoming in many cases dominant.

Calluna vulgaris has two zones of occurrence. The "mineral" sub-type is found on soils which are "wet", but where no drainage impedance can be observed. The "organic" sub-type is found where /

where true peat is present, contrasting with the previous sub-type where aerobic conditions indicate the humus layer to be a mor rather than a peat. The peats may be very "wet" and both sub-types are extremely acid and base saturation is very low.

Where Nardus stricta is dominant, two sub-types are again present - one on peat and one on a "mineral" soil. Unlike Calluna however, the Nardus sub-types exhibit a tolerance of "wetness", acidity and base saturation which overlaps that of the four other vegetation types.

In an area such as the one investigated, the main factor modifying the vegetation is biotic. This includes not only the effect of the grazing animal but also that of fire. Of the vegetation types examined, those dominated by Calluna and Molinia are the only two commonly burned as part of the sheep farming policy, and the findings show that, given favourable conditions, Nardus stricta can colonise these soil types. It seems unlikely that Nardus would be able to spread to any great extent into the base-rich flushed areas of the Agrostis types. Here the better grasses are able to maintain themselves even under extreme grazing pressure, indicating the primary factor to be edaphic. Scattered tussocks of Nardus are commonly present in the Deschampsia flexuosa vegetation /

vegetation type. Though the acidity and Loss on Ignition ranges of this type are very near the optima for the "mineral" Nardus type, the W/H ratio results show that the Deschampsia type is exceedingly "dry". This factor may limit a large scale colonisation by Nardus of the Deschampsia type.

SECTION 9

SUMMARY

SUMMARY.

1. Introduction, scope and plan of this thesis.

2. A review of literature having a bearing on the investigation.

3. The Soils of Sourhope described with reference to the Macauly Soils Survey and the method used in soil sampling.

4. Main vegetation types occurring in this area, with a reference to the former distribution of woodland. The percentage specific frequency method of vegetation analysis, and reasons for the choice of this method.

5. A detailed description of the five vegetation types investigated. The range of Loss on Ignition, Water/Humus ratio, pH, percentage exchangeable calcium, and available phosphates and potassium. Soil profile diagrams and vegetation analysis figures for each site examined.

6. The inter-relations of the five vegetation types with reference to the soil conditions prevailing in each.

7. The inter-relations of the various soil factors estimated, and a statistical examination of the pH and W/H results for each of the eight vegetation types and sub-types.

8. /

8. The distribution of the twenty principal hill species encountered on this project in relation to soil conditions.

9. Conclusions.

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APPENDIX I.

Site	Sample No.	Humus %	Water %	W/H	pH	P_2O_5	K_2O	Ex. Ca. %
1	41	41.70	132.0	3.2	4.7	13	0.46	0.035
	S 42	10.40	20.0	1.9	5.2	13	0.41	0.010
	43	20.50	63.0	3.1	5.1	10	0.32	0.023
	S 44	17.10	37.80	2.3	5.0	6	0.71	0.039
	45	24.20	50.70	2.1	4.5	7	0.65	0.037
	S 46	18.40	40.00	2.2	4.8	8	0.70	0.019
	47	30.30	61.50	2.0	4.4	6	0.70	0.046
	48	39.30	123.0	3.1	4.5	9	0.68	0.048
	49	32.20	90.60	2.7	4.5	9	0.69	0.039
	50	32.50	104.0	3.2	4.5	11	0.70	0.033
	51	23.30	62.0	2.7	4.5	8	0.72	0.035
	52	23.70	46.50	2.0	4.5	9	0.63	0.033
	53	22.00	79.00	3.6	4.5	7	0.57	0.035
2	54	19.70	51.60	2.6	4.7	9	0.39	0.023
	S 55	11.50	30.60	2.8	5.6	4	0.40	0.008
	56	39.00	96.60	2.5	4.9	12	0.77	0.027
	S 57	25.70	47.30	1.8	5.5	8	0.41	0.085
	58	34.60	91.70	2.7	4.6	8	0.69	0.037
	S 59	14.20	28.80	2.1	5.4	7	0.54	0.054
	60	32.40	42.00	1.3	4.6	7	0.81	0.042
	61	41.00	85.40	2.1	4.6	7	0.59	0.035
	62	30.50	42.50	1.4	4.7	13	0.71	0.033
	63	37.20	45.50	1.2	4.7	9	0.84	0.044
	64	31.20	25.40	0.85	4.4	9	0.70	0.035
	65	20.80	40.00	1.9	4.4	7	0.72	0.039
	66	50.50	91.50	1.8	4.2	8	0.77	0.052

Site	Sample No.	Humus %	Water %	W/H	pH	P_2O_5	K_2O	Ex. Ca. %
3	67	18.70	29.70	1.6	5.0	10	0.80	0.043
	S 68	11.70	28.20	2.4	5.2	11	0.47	0.014
	69	19.50	17.40	0.9	5.0	10	0.70	0.025
	S 70	9.90	25.20	2.5	4.7	5	0.55	0.030
	71	23.60	33.00	1.4	4.3	15	0.44	0.017
	S 72	11.10	25.70	2.3	4.7	16	0.40	0.018
	73	19.40	37.00	1.9	4.1	15	0.59	0.046
	74	17.00	21.00	1.2	4.5	8	0.63	0.021
	75	16.40	33.60	2.0	4.3	14	0.66	0.027
	76	24.20	26.40	1.1	4.1	7	0.74	0.025
	77	12.80	12.70	1.0	4.3	7	0.52	0.031
	78	19.50	21.40	1.1	4.2	8	0.68	-
	79	18.00	13.10	0.73	4.3	14	0.68	0.035
4	80	20.80	19.10	0.92	4.9	15	0.80	0.031
	S 81	13.30	20.40	1.50	5.4	15	0.76	0.046
	S 82	9.10	18.40	2.0	5.8	11	0.65	-
	83	21.20	23.40	1.1	5.2	7	0.53	0.035
	S 84	11.60	32.00	2.8	4.8	15	0.45	0.071
	S 85	7.40	13.70	1.85	5.2	14	0.48	-
	86	22.10	23.30	1.06	4.6	15	0.51	0.035
	S 87	18.70	27.40	1.45	4.8	13	0.40	0.071
	88	25.40	23.00	0.91	4.7	26	0.79	0.023
	S 89	30.60	24.70	0.82	4.8	18	0.44	-
	90	26.60	20.80	0.78	4.5	16	0.64	-
	91	27.20	19.80	0.73	4.5	16	0.71	-
	92	29.70	23.30	0.78	4.4	16	0.84	-
	93	34.00	36.10	1.06	4.4	11	0.96	0.032
	94	28.70	20.90	0.73	4.5	12	0.63	0.035
	95	29.00	30.50	1.05	4.3	11	0.62	0.040
	96	25.20	14.00	0.56	4.5	10	1.00	0.030

Site	Sample No.	Humus %	Water %	W/H	pH	P_2O_5	K_2O	Ex. Ca. %
5	97	83.20	238.0	2.90	4.4	13	0.23	-
	S 98	82.00	310.0	3.80	4.8	5	0.55	-
	99	85.00	220.0	2.80	4.4	13	0.76	-
	S100	86.00	293.0	3.40	4.4	6	0.52	-
	101	94.50	249.0	2.60	4.4	12	0.64	0.066
	102	96.00	264.0	2.70	4.0	10	0.74	-
	103	95.00	283.0	3.00	4.3	10	0.77	-
6	104	24.50	24.90	1.05	4.9	7	0.70	0.090
	S 105	13.80	23.40	1.70	5.5	7	0.47	0.126
	106	19.50	16.50	0.85	4.7	10	0.56	-
	S 107	12.20	29.60	2.40	5.3	6	0.49	0.066
	108	18.20	35.40	2.0	5.6	4	0.53	0.140
	S 109	14.30	31.60	2.2	5.7	5	0.56	0.152
	110	18.60	21.70	1.20	4.7	5	0.62	0.076
	111	16.50	35.0	2.1	5.5	4	0.52	0.148
	112	21.20	23.80	1.1	4.6	11	0.45	-
	113	27.90	35.0	1.[illegible]	4.6	9	0.60	0.048
	114	22.00	28.30	1.30	4.8	7	0.65	0.070
	115	22.90	27.00	1.17	4.5	13	0.58	0.042
	116	21.60	26.00	1.20	4.8	7	0.55	0.100

Site	Sample No.	Humus%	Water %	W/H	pH	P_2O_5	K_2O	Ex. Ca. %
7	117	25.40	29.60	1.17	4.8	15	0.82	0.021
	S 118	12.20	31.60	2.60	5.3	18	0.20	0.027
	119	17.90	30.40	1.70	5.0	14	0.55	0.019
	S 120	13.70	31.80	2.30	4.8	28	0.40	0.020
	121	17.20	19.80	1.16	4.5	16	0.47	0.037
	S 122	12.60	26.20	2.10	4.6	22	0.38	0.018
	123	25.70	19.50	0.76	4.4	18	0.60	0.020
	124	22.70	24.80	1.10	4.3	14	0.63	-
	125	22.70	28.80	1.27	4.4	15	0.69	0.020
	126	22.20	21.80	0.98	4.6	24	0.76	0.020
	127	21.70	16.80	0.78	4.5	20	0.93	0.016
	128	23.50	23.40	1.00	4.3	26	0.71	0.030
	129	21.50	18.80	0.87	4.3	18	0.71	0.024
8	130	16.30	20.05	1.24	5.3	9	0.72	0.112
	S 131	13.50	23.50	1.74	5.1	6	0.67	0.052
	132	14.90	24.50	1.57	5.2	6	0.63	0.076
	S 133	11.30	24.60	2.18	5.2	9	0.57	0.106
	134	17.60	33.00	1.88	5.0	9	0.46	0.068
	S 135	15.20	36.30	2.40	5.2	11	0.38	0.096
	136	22.90	24.00	1.05	4.6	13	0.66	0.052
	137	20.40	20.50	1.00	4.7	10	0.68	0.048
	138	23.80	27.60	1.16	4.9	4	0.73	0.048
	139	22.50	25.50	1.14	4.6	3	0.70	0.058
	140	17.20	18.20	1.05	4.9	4	0.61	0.075
	141	17.30	22.30	1.29	4.9	8	0.55	0.072
	142	23.40	23.30	1.00	4.8	8	0.93	0.032

Site	Sample No.	Humus %	Water %	W/H	pH	P_2O_5	K_2O	Ex. Ca. %
9	143	14.70	20.80	1.43	5.1	4	0.53	0.060
	S 144	10.50	26.00	2.48	5.6	5	0.51	0.060
	145	21.40	25.40	1.20	4.9	4	0.72	0.037
	S 146	12.70	31.40	2.46	5.2	3	0.48	0.070
	147	16.90	18.80	1.11	4.5	3	0.53	0.044
	S 148	10.10	19.10	1.89	5.3	5	0.25	0.084
	149	14.70	31.40	2.14	5.1	4	0.62	0.048
	150	18.90	19.80	1.05	5.0	4	0.56	0.050
	151	14.80	23.40	1.58	5.1	3	0.46	0.050
	152	14.70	23.80	1.62	4.5	4	0.52	0.052
	153	22.30	23.20	1.04	5.2	20	0.51	0.097
	154	19.70	37.40	1.90	4.6	7	0.56	0.040
	155	14.50	29.80	2.05	4.9	4	0.48	0.064
10	156	71.50	217.0	3.03	4.3	11	0.82	0.044
	S 157	11.60	40.50	3.48	5.2	6	0.28	0.020
	158	44.20	131.0	2.98	4.4	11	0.60	0.087
	S 159	11.20	37.50	3.36	5.3	7	0.23	0.020
	160	75.8	254.0	3.35	4.5	12	0.73	0.079
	S 161	9.5	34.5	3.45	5.3	7	0.18	0.016
	162	86.2	365.0	4.24	4.6	11	0.62	0.152
	163	88.6	411.0	4.63	4.6	15	0.81	0.068
	164	78.6	253.0	3.22	4.6	8	0.69	0.072
	165	77.9	364.0	4.66	4.7	10	0.70	0.094
	166	85.2	327	3.84	4.5	10	0.70	0.048
	167	67.3	262	3.88	4.4	14	0.66	0.066
	168	64.1	244	3.81	4.4	11	0.37	0.054

Site	Sample No.	Humus %	Water %	W/H	pH	P_2O_5	K_2O	Ex. Ca. %
11	169	89.8	382	4.24	4.3	5	0.55	-
	S 170	18.4	68.3	3.71	4.6	5	0.27	0.028
	171	88.7	273	3.08	4.3	9	0.86	0.068
	S 172	14.7	56.8	3.86	4.5	4	0.22	0.020
	173	87.9	262	3.13	4.3	11	0.87	0.050
	S 174	16.2	61.0	3.76	4.7	5	0.26	0.037
	175	87.3	298	3.42	4.3	12	0.91	0.048
	176	89.2	314	3.52	4.1	9	0.74	0.050
	177	89.2	309	3.46	4.5	11	0.66	-
	178	87.7	371	4.22	4.6	20	0.71	-
	179	90.0	293	3.23	4.2	13	0.48	0.042
	180	90.4	315	3.48	4.3	11	0.47	0.056
	181	89.6	335	3.73	4.4	11	0.43	0.042
12	182	54.6	126.5	2.32	4.3	9	0.30	0.056
	S 183	18.3	41.8	2.29	4.6	15	0.18	0.022
	184	45.9	98.6	2.15	4.3	10	0.37	-
	S 185	13.9	32.7	2.35	4.9	20	0.21	0.012
	186	70.3	163.0	2.31	4.2	35	0.35	0.028
	S 187	24.2	42.4	1.75	4.7	26	0.14	0.020
	188	77.3	195.0	2.52	4.6	18	0.42	0.092
	189	85.8	234.0	2.66	4.3	12	0.39	-
	190	79.3	229.0	2.88	4.3	15	0.37	0.138
	191	45.3	137.5	3.03	4.3	13	0.42	0.032
	192	68.5	213.0	3.11	4.4	15	0.51	0.064
	193	64.2	168.0	2.62	4.5	14	0.44	0.062
	194	80.8	238.0	2.94	4.4	14	0.52	0.056

Site	Sample No.	Humus %	Water %	W/H	pH	P_2O_5	K_2O	Ex. Ca. %
13	195	24.6	34.8	1.41	4.4	10	0.38	0.083
	S 196	10.75	17.1	1.59	5.3	50	0.29	0.014
	197	19.65	22.3	1.14	4.4	22	0.32	0.064
	S 198	25.40	35.4	1.39	5.6	50	0.20	-
	199	18.8	25.1	1.34	4.6	22	0.31	0.066
	S 200	11.05	19.00	1.72	5.1	45	0.24	0.022
	201	28.5	29.70	1.04	4.3	12	0.42	0.028
	202	33.6	33.10	0.99	4.4	10	0.56	0.032
	203	22.7	24.70	1.09	4.5	8	0.45	0.024
	204	34.3	41.00	1.19	4.4	11	0.60	0.028
	205	28.9	32.10	1.11	4.4	11	0.55	0.030
	206	27.3	35.50	1.30	4.2	15	0.44	0.100
	207	26.5	30.80	1.16	4.4	9	0.43	0.033
14	208	81.4	308.0	3.78	4.2	12	0.60	-
	S 209	37.6	116.0	3.08	4.9	15	0.27	0.042
	210	88.3	323.0	3.66	4.3	11	0.52	0.072
	S 211	42.5	109.0	2.57	4.7	18	0.28	0.052
	212	87.9	341.0	3.87	4.3	13	0.52	-
	S 213	45.2	112.0	2.47	5.0	18	0.22	0.064
	214	85.5	358.0	4.18	4.2	12	0.45	-
	215	76.4	287.0	3.76	4.5	14	0.60	-
	216	86.5	314.0	3.64	4.2	13	0.45	-
	217	81.0	285.0	3.51	4.2	14	0.41	0.120
	218	75.0	257.0	3.52	4.7	18	0.42	-
	219	85.0	303.0	3.56	4.1	15	0.29	0.131
	220	89.0	381.0	4.27	4.3	18	0.38	0.091

Site	Sample No.	Humus %	Water %	W/H	pH	P_2O_5	K_2O	Ex. Ca. %
15	222	83.2	244.0	2.93	4.5	15	0.49	0.106
	S 223	13.7	34.0	2.49	5.1	12	0.13	0.052
	224	64.0	189.0	2.95	4.6	13	0.42	0.050
	S 225	13.7	39.1	2.85	5.2	5	0.19	0.033
	226	61.2	189.0	3.08	4.5	15	0.52	0.060
	S 227	15.5	31.3	2.02	5.1	16	0.14	0.014
	228	61.0	177.0	2.91	4.4	13	0.41	-
	229	57.6	168.0	2.94	4.5	13	0.38	0.086
	230	77.5	259.0	3.34	4.4	9	0.40	-
	231	68.4	186.0	2.72	4.5	13	0.37	-
	232	54.7	80.2	1.47	4.6	9	0.45	0.035
	233	86.8	329.0	3.79	4.5	10	0.34	0.100
	234	68.0	179.0	2.60	4.4	15	0.37	-
17	251	89.6	251.0	2.80	4.3	15	1.30	0.066
	S 252	29.9	23.2	0.78	5.0	12	0.17	0.014
	253	88.4	252.0	2.85	4.1	10	0.90	0.106
	S 254	21.2	37.2	1.76	5.2	7	0.17	-
	255	82.8	199.0	2.40	4.2	14	0.74	0.118
	S 256	16.9	37.1	2.20	5.3	11	0.17	0.030
	257	71.2	139.0	1.96	4.2	12	0.77	-
	S 258	21.0	42.2	2.01	5.2	12	0.30	0.040
omit	(259	13.4	17.6	1.33	4.6	13	0.37	0.040
	(S 260	11.9	29.5	2.48	6.0	18	0.25	0.078
	261	91.7	325.0	3.54	4.5	13	0.83	0.060
	262	85.5	247.0	2.89	4.2	15	0.96	0.095
	263	86.7	182.0	2.10	4.3	15	1.01	-
	264	87.5	317.0	3.62	4.5	13	0.70	-
	265	89.7	302.0	3.37	4.4	18	0.98	0.090
	266	83.0	209.0	2.51	4.3	20	0.96	-
	267	86.5	276.0	3.18	4.3	16	1.00	0.050
	268	42.2	82.5	1.95	4.3	15	0.56	0.070

Site	Sample No.	Humus %	Water %	W/H	pH	P_2O_5	K_2O	Ex. Ca. %
19	287	22.50	51.0	2.26	4.5	4	0.85	0.040
	288	21.30	24.6	1.16	4.7	4	0.56	0.046
	289	25.60	47.6	1.86	4.7	4	0.54	0.026
	290	23.20	35.2	1.52	4.8	5	0.66	0.024
	291	21.60	34.9	1.62	4.6	4	0.64	0.020
	292	21.80	44.6	2.04	4.7	5	0.64	0.039
20	293	20.60	54.1	2.63	4.8	9	0.51	0.033
	294	27.10	81.4	3.01	4.5	10	0.54	0.022
	295	29.90	63.4	2.12	4.5	12	0.59	0.035
	296	31.20	70.2	2.25	4.6	8	0.55	0.046
	297	23.10	71.3	3.08	4.6	5	0.67	0.039
	298	23.4	68.0	2.91	4.5	4	0.51	0.035
22	305	32.1	66.6	2.07	4.7	3	0.73	0.030
	306	36.0	79.8	2.22	4.7	6	0.67	0.028
	307	26.6	51.0	1.96	4.6	4	0.61	0.035
	308	24.6	60.6	2.46	4.8	5	0.51	0.037
	309	28.7	68.0	2.37	4.5	3	0.74	0.046
	310	29.5	86.0	2.91	4.6	5	0.68	0.030

Site	Sample No.	Humus %	Water %	W/H	pH	P_2O_5	K_2O	Ex. Ca. %
36	391	20.2	53.8	2.67	5.2	5	0.51	0.028
	S 392	12.0	27.9	2.32	5.2	24	0.21	0.016
	393	18.5	46.3	2.51	4.9	5	0.49	0.026
	S 394	11.15	23.8	2.13	5.4	22	0.20	0.048
	395	20.2	52.7	2.61	5.1	4	0.50	0.022
	396	21.1	52.4	2.49	5.2	5	0.56	0.026
	397	19.3	49.6	2.57	5.3	4	0.58	0.035
	398	16.8	43.3	2.58	4.9	9	0.57	0.016
	399	20.8	47.2	2.27	4.9	6	0.82	0.022
	400	19.2	42.5	2.22	5.0	7	0.62	0.022
37	406	75.5	262.0	3.46	4.3	10	0.87	-
	S 407	22.5	41.6	1.85	5.2	13	0.38	-
	408	39.4	135.0	3.42	4.4	5	0.76	-
	S 409	19.7	53.0	2.69	5.0	10	0.45	-
	410	75.0	357.0	4.65	4.1	5	0.94	-
	411	70.5	252.0	3.58	4.4	6	0.94	-
	412	90.0	360.0	4.00	4.3	9	0.90	-
	413	92.6	422.0	4.56	4.2	4	0.94	-
	414	72.2	267.0	3.69	4.7	Tr	0.91	-
	415	88.4	354.0	4.00	4.2	Tr	1.02	-
	416	90.5	343.0	3.79	4.3	3	0.95	-
	417	89.4	349.0	3.90	4.1	6	0.90	-

Site	Sample No.	Humus %	Water %	W/H	pH	P_2O_5	K_2O	Ex. Ca. %
38	418	12.9	47.3	3.67	5.5	3	0.63	-
	S 419	5.93	21.3	3.58	5.7	6	0.55	-
	420	11.4	43.6	3.82	5.6	Tr	0.60	-
	S 421	5.56	26.3	4.72	5.8	3	0.52	-
	422	11.70	38.5	3.30	5.5	Tr	0.52	-
	S 423	7.60	23.3	3.07	5.6	Tr	0.46	-
	424	12.80	40.5	3.17	5.6	Tr	0.61	-
	425	12.75	44.1	3.45	5.8	Tr	0.56	-
	426	12.62	39.7	3.15	5.7	Tr	0.56	-
	427	11.78	43.4	3.69	5.7	Tr	0.58	-
	428	12.96	37.5	2.89	5.6	3	0.45	-
	429	12.85	41.1	3.20	5.7	Tr	0.66	-
	430	12.00	44.5	3.71	5.6	Tr	0.53	-
39	431	12.70	52.9	4.17	5.6	Tr	0.56	0.079
	S 432	5.93	21.6	3.65	6.0	6	0.37	0.054
	433	12.05	46.9	3.90	5.6	Tr	0.53	0.066
	S 434	6.08	23.1	3.80	5.9	Tr	0.29	-
	435	14.80	54.00	3.65	5.7	Tr	0.65	0.092
	S 436	6.68	23.95	3.58	5.9	3	0.48	0.059
	437	13.60	49.50	3.64	5.6	Tr	0.59	0.085
	438	12.78	51.80	4.06	5.6	3	0.48	0.073
	439	14.30	56.40	3.94	5.4	Tr	0.44	0.078
	440	16.25	66.70	4.10	5.5	Tr	0.55	0.070
	441	13.30	54.00	4.06	5.6	3	0.57	0.080
	442	13.80	55.0	3.99	5.6	Tr	0.49	0.079
	443	15.40	64.90	4.22	5.5	Tr	0.36	0.088

Site	Sample No.	Humus %	Water %	W/H	pH	P_2O_5	K_2O	Ex. Ca. %
40	444	14.90	53.0	3.56	5.7	Tr	0.47	0.127
	S 445	7.30	26.9	3.69	6.0	Tr	0.40	-
	446	14.45	44.5	3.08	5.8	Tr	0.50	0.148
	S 447	6.29	23.3	3.70	6.0	5	0.48	0.102
	448	17.55	55.7	3.18	6.0	Tr	0.51	0.161
	S 449	6.15	23.25	3.78	6.0	4	0.43	0.105
	450	16.80	56.30	3.35	5.7	Tr	0.60	0.132
	451	16.35	60.09	3.72	5.6	Tr	0.63	0.130
	452	15.10	53.40	3.54	5.7	Tr	0.61	0.157
	453	15.68	65.10	4.15	5.7	Tr	0.63	0.171
	454	19.28	64.00	3.32	5.8	Tr	0.61	0.190
	455	18.90	69.30	3.67	5.7	Tr	0.62	0.166
	456	16.30	54.40	3.34	5.7	Tr	0.57	0.174
41	457	52.10	130.0	2.49	4.4	3	0.74	-
	S 458	10.63	28.70	2.70	4.9	3	0.45	-
	459	42.60	102.2	2.40	4.3	5	0.71	-
	S 460	13.95	40.60	2.81	5.2	24	0.48	-
	461	43.20	102.0	2.36	4.4	10	0.77	-
	S 462	14.70	31.30	2.13	5.0	10	0.56	-
	463	27.50	66.10	2.40	4.5	5	0.74	-
	464	30.60	74.20	2.43	4.5	4	0.79	-
	465	42.30	103.0	2.43	4.5	11	0.79	-
	466	56.70	140.0	2.47	4.5	6	0.78	-
	467	51.90	122.8	2.37	4.1	7	0.94	-
	468	51.30	137.1	2.68	4.4	18	0.92	-
	469	40.60	99.20	2.44	4.4	7	0.79	-

Site	Sample No.	Humus %	Water %	W/H	pH	P_2O_5	K_2O	Ex. Ca. %
42	470	80.40	324.3	4.03	4.4	4	0.83	-
	S 471	25.60	58.40	2.28	5.0	5	0.38	-
	472	92.80	384.0	4.14	4.2	5	0.89	-
	S 473	14.22	39.70	2.80	5.1	8	0.35	-
	474	68.70	183.0	2.66	4.0	5	0.93	-
	S 475	18.20	54.80	3.01	5.2	13	0.34	-
	476	85.50	267.0	3.13	4.2	6	0.91	-
	477	90.30	339.0	3.75	4.2	7	0.97	-
	478	81.30	323.0	3.97	4.0	5	0.82	-
	479	87.80	273.0	3.11	4.4	4	0.87	-
	480	90.80	301.0	3.32	4.2	Tr	0.88	-
	481	93.00	278.0	2.99	4.0	Tr	0.86	-
	482	91.70	289.0	3.15	4.0	5	0.95	-
43	483	91.10	292.0	3.20	4.0	5	0.88	-
	S 484	21.75	68.60	3.15	4.9	12	0.39	-
	485	84.80	245.0	2.89	3.9	4	0.79	-
	S 486	11.64	35.20	3.20	4.8	15	0.36	-
	487	80.40	252.0	3.13	4.0	5	0.78	-
	S 488	13.30	44.9	3.38	5.0	8	0.43	-
	489	86.80	314.0	3.62	4.0	5	0.91	-
	9 490	83.40	249.0	2.98	4.0	4	0.84	-
	491	89.70	279.0	3.11	4.0	4	0.79	-
	492	91.80	304.0	3.31	4.1	5	0.95	-
	493	75.60	296.0	3.92	4.0	5	0.76	-
	494	78.70	224.0	2.85	4.0	5	0.93	-
	495	84.80	265.0	3.12	4.1	5	0.80	-

Site	Sample No.	Humus %	Water %	W/H	pH	P_2O_5	K_2O	Ex. Ca. %
44	496	17.83	41.60	2.34	4.9	6	0.64	-
	S 497	10.33	22.15	2.12	5.6	30	0.34	-
	498	17.40	45.40	2.61	5.0	6	0.56	-
	S 499	8.45	19.50	2.31	5.4	28	0.39	-
	500	14.10	38.2	2.71	5.1	7	0.57	-
	S 501	6.42	14.35	2.22	5.4	26	0.37	-
	502	18.10	54.60	3.20	4.7	10	0.55	-
	503	18.00	53.40	2.97	4.8	12	0.69	-
	504	21.80	71.00	3.26	4.7	5	0.67	-
	505	19.70	64.20	3.26	4.7	5	0.74	-
	506	20.70	57.40	2.78	4.8	5	0.71	-
	507	21.80	48.20	2.21	4.4	10	0.67	-
	508	20.90	49.20	2.35	4.7	7	0.65	-
45	509	22.20	64.80	2.94	5.4	Tr	0.52	-
	S 510	8.85	23.30	2.64	6.0	Tr	0.42	-
	511	17.75	55.00	3.10	5.4	Tr	0.59	-
	S 512	9.06	25.60	2.83	6.0	9	0.39	-
	513	20.50	70.30	3.43	5.5	3	0.47	-
	S 514	8.31	29.10	3.51	6.2	8	0.32	-
	515	20.00	60.60	3.03	5.3	Tr	0.53	-
	516	17.75	54.40	3.07	5.4	Tr	0.57	-
	517	18.65	55.80	2.99	5.4	3	0.43	-
	518	21.30	79.40	3.73	5.4	Tr	0.59	-
	519	19.20	62.70	3.27	5.4	Tr	0.61	-
	520	19.60	50.40	2.57	5.2	Tr	0.66	-
	521	22.70	80.00	3.53	5.4	Tr	0.57	-

Site	Sample No.	Humus %	Water %	W/H	pH	P_2O_5	K_2O	Ex. Ca. %
46	522	88.20	273.5	3.10	3.9	Tr	0.74	-
	S 523	16.30	40.30	2.47	5.3	6	0.46	-
	524	92.20	273.0	2.96	3.8	3	0.78	-
	S 525	14.14	37.85	2.68	5.2	15	0.38	-
	526	86.20	367.0	4.26	4.0	5	0.70	-
	S 527	15.16	43.5	2.87	4.9	10	0.43	-
	528	91.70	322.0	3.51	3.8	4	0.88	-
	529	92.50	322.0	3.48	3.9	Tr	0.81	-
	530	90.20	357.5	3.96	3.9	4	0.90	-
	531	83.10	272.0	3.25	4.0	4	0.74	-
	532	88.70	306.0	3.45	3.8	4	0.95	-
	533	90.0	323.0	3.59	3.8	7	0.86	-
	534	91.9	412.0	4.48	4.0	4	0.80	-
47	535	81.00	295.0	3.64	3.9	Tr	0.55	-
	S 536	13.35	36.30	2.72	5.0	Tr	0.32	0.002
	537	92.60	382.5	4.13	3.7	4	0.74	-
	S 538	9.50	33.45	3.52	4.8	Tr	0.29	0.002
	539	78.10	245.5	3.14	3.9	5	0.74	-
	S 540	9.61	38.8	4.04	5.0	Tr	0.37	0.001
	541	89.20	345.0	3.87	3.8	5	0.71	0.064
	542	75.10	206.5	2.75	3.9	10	0.83	0.022
	543	93.00	434.0	4.67	3.7	4	0.90	0.046
	544	91.70	314.0	3.42	3.5	4	0.95	0.010
	545	84.60	281.0	3.32	3.7	5	1.00	0.027
	546	55.60	176.2	3.17	3.7	15	0.85	0.022
	547	66.00	196.8	2.98	3.7	6	0.85	0.021

Site	Sample No.	Humus %	Water %	W/H	pH	P_2O_5	K_2O	Ex. Ca. %
48	548	16.47	77.7	4.71	5.1	15	0.63	-
	549	41.70	221.0	5.30	5.0	5	0.80	-
	550	33.90	172.5	5.09	4.8	10	0.75	-
	551	24.90	93.8	3.76	5.1	4	0.84	-
	552	45.60	197.5	4.33	5.2	5	0.68	-
	553	57.40	292.5	5.09	5.0	4	0.95	-
	554	31.90	131.9	4.14	5.0	5	0.75	-
	555	37.50	157.5	4.20	4.7	6	0.77	-
	556	33.20	124.5	3.75	4.9	5	0.73	-
	557	37.80	195.5	5.17	5.0	3	0.87	-
49	558	14.48	35.00	2.42	4.6	Tr	0.64	-
	S 559	11.18	27.60	2.45	4.9	Tr	0.35	-
	560	15.94	38.60	2.42	4.4	Tr	0.51	-
	561	18.70	44.40	2.38	4.3	Tr	0.61	-
	562	15.70	39.00	2.48	4.3	Tr	0.45	-
	563	19.70	49.80	2.53	4.2	Tr	0.61	-
	564	21.24	56.20	2.64	3.9	Tr	0.66	-
	565	18.60	43.90	2.36	4.3	Tr	0.50	-
	566	17.05	41.40	2.43	4.1	Tr	0.48	-
	567	22.30	52.80	2.37	3.8	Tr	0.57	-
	568	16.55	40.60	2.45	4.2	Tr	0.51	-

Site	Sample No.	Humus %	Water %	W/H	pH	P_2O_5	K_2O	Ex. Ca. %
50	569	32.60	111.00	3.41	4.9	4	0.58	0.069
	S 570	17.45	74.40	4.26	5.2	Tr	0.51	0.078
	571	34.30	142.20	4.15	5.2	Tr	0.72	0.069
	S 572	14.40	66.10	4.59	5.6	Tr	0.46	0.083
	573	23.64	98.80	4.18	5.3	Tr	0.58	0.085
	S 574	13.70	58.80	4.29	5.4	Tr	0.42	0.087
	575	28.20	118.30	4.20	5.1	5	0.63	0.139
	576	31.60	129.20	4.09	5.3	4	0.59	0.107
	577	34.80	146.40	4.21	5.0	Tr	0.53	0.083
	578	24.90	90.00	3.62	5.3	Tr	0.68	0.087
	579	25.10	117.40	4.67	5.4	Tr	0.66	0.107
	580	27.10	108.50	4.01	5.3	Tr	0.54	0.115
	581	23.95	93.10	3.89	5.1	Tr	0.71	0.120
51	582	17.30	45.80	2.66	5.2	Tr	0.67	-
	S 583	9.47	37.90	4.00	5.4	15	0.54	-
	584	18.80	57.80	3.08	4.9	4	0.63	-
	S 585	8.55	33.15	3.88	5.6	8	0.54	-
	586	17.56	53.10	3.03	5.1	Tr	0.65	-
	S 587	9.47	41.20	4.35	5.7	8	0.50	-
	588	20.40	62.20	3.55	4.8	4	0.76	-
	589	20.65	51.30	2.49	4.9	5	0.78	-
	590	19.10	53.90	2.72	4.7	Tr	0.74	-
	591	20.10	58.70	2.92	4.6	Tr	0.86	-
	592	18.75	48.10	2.56	4.9	4	0.84	-
	593	19.50	49.20	2.52	5.1	7	0.80	-
	594	17.35	47.10	2.72	4.7	8	0.95	-

Site	Sample No.	Humus %	Water %	W/H	pH	P_2O_5	K_2O	Ex. Ca. %
52	595	26.15	74.80	2.84	4.2	20	0.70	-
	S 596	12.90	26.70	2.07	5.1	26	0.59	-
	597	21.85	63.60	2.92	4.2	15	0.68	-
	S 598	6.55	13.30	2.03	4.9	45	0.47	-
	599	20.85	61.30	2.94	4.1	11	0.71	-
	S 600	10.50	33.80	3.22	4.8	26	0.48	-
	601	24.10	79.10	3.28	4.1	5	0.71	0.007
	602	25.55	80.10	3.08	4.0	6	0.61	0.011
	603	23.40	72.00	3.08	4.3	11	0.70	0.010
	604	28.15	94.60	3.36	4.1	10	0.82	0.013
	605	32.70	106.0	3.24	3.9	12	0.85	0.022
	606	23.65	79.0	3.35	4.1	7	0.78	0.011
	607	25.40	87.2	3.43	3.8	12	0.76	0.021
53	608	32.00	81.0	2.53	3.9	6	0.67	-
	S 609	12.63	48.3	3.82	4.9	20	0.59	0.002
	610	38.55	115.0	2.87	3.8	7	0.84	-
	S 611	15.59	53.2	3.42	4.7	13	0.56	0.003
	612	47.30	119.5	2.53	3.6	6	0.75	-
	S 613	16.67	58.7	3.52	4.5	16	0.63	0.003
	614	24.00	71.70	2.99	4.0	3	0.71	0.014
	615	57.40	160.0	2.79	3.8	4	0.80	0.015
	616	50.10	132.90	2.66	3.8	3	0.83	0.035
	617	33.10	90.10	2.72	3.8	Tr	0.66	0.008
	618	33.70	102.8	3.05	3.9	3	0.69	0.015
	619	30.25	86.4	2.83	3.9	6	0.74	0.024
	620	45.10	126.0	2.79	3.8	6	0.83	0.010

Site	Sample No.	Humus %	Water %	W/H	pH	P_2O_5	K_2O	Ex. Ca. %
54	621	34.75	101.0	2.91	3.8	9	0.81	-
	S 622	6.97	27.9	4.02	4.8	70	0.59	-
	623	32.60	95.7	2.94	3.8	15	0.76	-
	S 624	5.58	25.35	4.54	4.9	70	0.52	-
	625	30.15	87.30	2.89	3.8	12	0.73	-
	S 626	6.20	24.95	4.03	4.7	45	0.52	-
	627	39.40	121.3	3.08	3.7	7	0.77	-
	628	48.80	145.7	2.98	3.5	11	0.87	-
	629	25.30	79.8	3.16	3.8	8	0.75	-
	630	41.80	110.0	2.63	3.6	6	0.67	-
	631	39.3	108.7	2.76	3.6	8	0.72	-
	632	52.5	139.0	2.65	3.6	9	0.89	-
	633	33.90	95.5	2.82	3.7	7	0.76	-
55	634	18.95	62.10	3.25	4.0	5	0.74	-
	S 635	8.04	25.75	3.20	5.0	45	0.49	-
	636	21.00	61.40	2.92	4.0	5	0.76	-
	S 637	9.42	26.42	2.81	5.5	22	0.58	-
	638	31.10	85.00	2.74	3.8	8	0.86	-
	S 639	11.42	33.65	2.94	4.7	22	0.63	-
	640	25.40	69.80	2.75	4.0	5	0.73	-
	641	27.15	63.80	2.35	3.8	3	0.70	-
	642	25.30	66.40	2.62	4.1	Tr	0.74	-
	643	29.85	71.20	2.38	4.0	Tr	0.82	-
	644	41.50	96.10	2.32	3.6	5	0.86	-
	645	39.50	107.1	2.72	3.5	5	0.85	-
	646	28.95	86.2	2.98	4.0	6	0.79	-

Site	Sample No.	Humus %	Water %	W/H	pH	P_2O_5	K_2O	Ex. Ca. %
56	647	93.50	347.0	3.71	3.6	Tr	1.00	-
	S 648	19.87	77.10	3.88	4.8	4	0.52	-
	649	89.10	362.5	4.06	3.7	5	0.98	-
	S 650	17.10	61.70	3.62	4.9	Tr	0.50	-
	651	87.20	391.5	4.48	4.0	Tr	0;83	-
	S 652	15.21	59.3	3.90	4.9	4	0.33	-
	653	92.20	346.5	3.76	3.7	Tr	1.06	-
	654	92.80	390.0	4.21	3.7	Tr	0.90	-
	655	94.10	395.5	4.20	3.6	Tr	0.91	-
	656	89.10	372.0	4.18	3.6	Tr	0.97	-
	657	95.20	451.0	4.73	3.6	5	0.94	-
	658	93.40	458.0	4.91	3.7	Tr	0.94	-
	659	95.00	371.0	3.91	3.7	Tr	1.00	-
57	660	97.4	447.0	4.59	3.6	Tr	1.01	-
	S 661	96.8	500.0	5.16	3.6	Tr	0.68	0.044
	S 662	97.4	520.0	5.34	3.8	Tr	0.55	0.038
	S 663	97.8	612.0	6.26	3.7	Tr	0.50	0.042
	664	96.10	444.0	4.62	3.4	4	0.84	0.049
	665	96.50	389.0	4.03	3.5	6	0.81	-
	666	95.70	496.0	5.18	3.5	4	0.94	0.051
	667	96.60	512.0	5.29	3.5	5	0.92	0.064
	668	95.50	303.0	3.17	3.6	4	0.80	0.053
	669	97.40	368.0	3.78	3.5	3	0.80	0.060
	670	96.50	399.0	4.14	3.6	5	0.99	-
	671	97.10	417.0	4.29	3.9	Tr	0.91	0.048
	672	95.90	443.0	4.62	3.8	5	0.80	-

Site	Sample No.	Humus %	Water %	W/H	pH	P_2O_5	K_2O	Ex. Ca. %
58	673	59.00	209.0	3.54	3.8	Tr	0.87	-
	S 674	9.63	34.0	3.52	5.0	24	0.38	-
	675	38.75	141.7	3.66	4.2	3	0.66	-
	S 676	13.40	41.7	3.11	5.0	14	0.34	0.005
	677	56.40	155.1	2.75	4.0	5	0.67	-
	S 678	10.92	32.5	2.98	4.8	18	0.36	-
	679	65.80	255.0	3.88	3.9	5	0.78	0.034
	680	62.00	238.0	3.83	3.8	4	0.75	0.048
	681	29.15	112.2	3.80	4.1	3	0.63	0.046
	682	35.95	113.2	3.15	4.4	Tr	0.69	0.020
	683	32.45	123.0	3.79	4.1	Tr	0.58	0.025
	684	50.70	178.3	3.52	3.7	Tr	0.85	-
	685	75.60	254.5	3.37	3.7	Tr	1.00	0.059
59	686	15.88	62.30	3.93	5.1	5	0.62	-
	S 687	6.28	28.60	4.55	5.5	18	0.36	-
	688	22.10	104.4	4.72	5.3	4	0.80	-
	S 689	6.61	33.7	5.10	5.5	18	0.39	-
	690	17.80	76.6	4.30	5.2	4	0.60	-
	S 691	9.56	39.7	4.15	5.6	14	0.38	-
	692	17.28	55.7	3.22	5.2	5	0.64	-
	693	16.78	81.3	4.84	5.3	5	0.62	-
	694	17.90	72.4	4.05	5.4	7	0.60	-
	695	18.77	[illegible]	3.95	5.5	4	0.69	-
	696	16.40	65.8	4.02	5.2	5	0.58	-
	697	15.56	71.20	4.57	5.4	5	0.53	-
	698	16.67	64.20	3.85	5.2	7	0.55	-

Site	Sample No.	Humus %	Water %	W/H	pH	P_2O_5	K_2O	Ex. Ca. %
60	699	28.40	90.30	3.18	3.9	5	0.60	-
	S 700	18.68	52.50	2.81	4.7	12	0.42	-
	701	42.80	121.00	2.81	3.8	8	0.73	-
	S 702	19.50	53.30	2.73	4.7	24	0.51	-
	703	34.80	100.5	3.46	3.8	6	0.81	-
	S 704	20.10	45.80	2.28	4.7	12	0.39	-
	705	33.00	103.5	3.14	3.9	9	0.78	-
	706	52.30	147.0	2.81	4.3	8	1.01	-
	707	41.50	116.0	2.80	3.7	5	0.83	-
	708	52.90	148.5	2.81	3.6	10	0.86	-
	709	36.60	113.5	3.11	4.0	7	0.90	-
	710	42.20	114.5	2.72	4.1	7	0.78	-
	711	26.50	78.5	2.96	3.8	7	0.76	-
61	712	95.8	673.0	7.02	3.8	Tr	0.96	-
	S 713	97.2	806.0	8.30	3.9	3	0.84	-
	S 714	98.7	1010.0	10.35	3.9	Tr	0.49	-
	S 715	98.3	870.0	8.95	3.7	Tr	0.49	-
	716	97.4	616.0	6.32	3.8	Tr	0.99	-
	717	96.3	790.0	8.20	4.2	Tr	1.14	-
	718	97.0	597.0	6.10	4.3	Tr	1.00	-
	719	97.5	680.0	6.98	4.0	Tr	1.22	-
	720	97.0	612.0	6.32	3.8	Tr	1.04	-
	721	97.5	560.0	5.73	3.8	Tr	0.96	-
	722	97.5	697.0	7.15	3.9	Tr	1.01	-
	723	97.5	593.0	6.07	3.8	Tr	0.64	-
	724	97.5	595.0	6.10	3.8	5	1.01	-

Site	Sample No.	Humus %	Water %	W/H	pH	P_2O_5	K_2O	Ex. Ca. %
62	725	24.0	16.60	0.69	5.0	3	1.01	-
	S 726	13.9	25.20	1.81	5.3	12	0.95	-
	727	22.0	16.80	0.76	4.9	3	0.80	-
	S 728	11.10	32.00	2.74	5.4	20	0.49	-
	729	19.00	20.00	1.06	5.0	7	0.81	-
	S 730	13.30	30.00	2.25	5.3	20	0.56	-
	731	24.00	29.20	1.22	4.9	6	0.82	-
	732	27.50	25.90	0.95	5.0	12	0.99	-
	733	31.00	23.30	0.75	4.8	9	0.98	-
	734	23.80	32.60	1.37	5.1	3	1.05	-
	735	28.00	30.40	1.08	4.8	3	0.87	-
	736	24.40	19.10	0.78	5.0	3	0.77	-
	737	23.10	35.40	1.54	4.8	3	0.78	-
63	738	23.40	49.50	2.12	4.5	3	0.83	-
	S 739	10.40	27.40	2.64	5.2	50	0.64	-
	740	21.60	63.50	2.94	4.4	3	0.84	-
	S 741	12.40	25.90	2.09	4.7	35	0.64	-
	742	22.30	55.70	2.50	4.5	3	0.77	-
	S 743	12.70	29.90	2.35	4.4	50	0.70	-
	744	25.60	64.00	2.51	4.4	5	0.94	-
	745	22.10	65.60	2.97	4.4	6	0.95	-
	746	26.20	75.90	2.90	4.3	7	0.85	-
	747	24.20	77.00	3.18	4.3	3	0.78	-
	748	23.60	67.40	2.86	4.5	3	0.82	-
	749	23.70	70.60	2.98	4.2	3	0.90	-
	750	24.30	59.80	2.46	4.3	5	0.82	-

APPENDIX II.

MEANS FOR SOIL FACTORS FOR EACH SITE EXAMINED GROUPED UNDER VEGETATION TYPES

CALLUNA VULGARIS

Topsoils

Site	n.	W/H	K_2O	pH	L.I.%	P_2O_5	Ex. Ca. %	n.
47	10	3.51	0.81	3.8	80.7	6.1	0.032	7
52	10	3.15	0.73	4.1	25.2	10.9	0.012	7
53	10	2.78	0.75	3.8	39.2	4.7	0.017	7
54	10	2.88	0.77	3.7	37.9	9.2	-	-
55	10	2.70	0.79	3.9	28.9	5.8	-	-
56	10	4.22	0.95	3.7	92.2	3.4	-	-
57	10	4.37	0.80	3.6	96.5	3.7	0.054	6
58	10	3.53	0.75	4.0	50.6	3.5	0.039	6
60	10	2.98	0.81	3.9	39.1	7.2	-	-
61	10	6.61	1.10	3.9	97.1	3.1	-	-

Subsoils

47	3	3.43	0.33	4.9	10.8	3.0	0.002	3
52	3	2.43	0.51	4.9	10.0	32.0	-	-
53	3	3.59	0.59	4.7	15.0	13.0	0.003	3
54	3	4.16	0.54	4.8	6.3	62.0	-	-
55	3	2.98	0.57	5.1	9.6	29.0	-	-
56	3	3.80	0.45	4.9	17.4	4.0	-	-
57	3	5.59	0.58	3.7	97.3	3.0	0.041	3
58	3	3.20	0.36	4.9	11.3	19.0	0.005	1
60	3	2.61	0.44	4.7	19.4	16.0	-	-
61	3	9.20	0.90	3.8	98.1	3.0	-	-

AGROSTIS FESCUE

Topsoils

Site	n.	W/H	K_2O	pH	L.I.%	P_2O_5	Ex. Ca. %	n.
6	10	1.3	0.58	4.9	21.3	7.7	0.089	8
8	10	1.2	0.67	4.9	19.6	7.4	0.064	10
9	10	1.5	0.55	4.9	17.3	5.7	0.054	10
39	10	4.0	0.52	5.6	13.9	3.0	0.079	10
40	10	3.5	0.58	5.7	16.5	3.0	0.155	10
44	10	2.8	0.65	4.8	19.0	7.3	-	-
45	10	3.2	0.55	5.4	10.0	3.0	-	-
48	10	4.6	0.78	5.0	36.0	6.2	-	-
50	10	4.0	0.62	5.2	28.6	3.4	0.098	10
51	10	2.8	0.77	4.9	19.0	4.4	-	-
59	10	4.2	0.62	5.3	17.5	5.1	-	-

Subsoils

6	3	2.1	0.51	5.5	13.4	6.0	0.116	3
8	3	2.1	0.51	5.2	13.3	9.0	0.085	3
9	3	2.3	0.41	5.3	11.1	4.0	0.071	3
39	3	3.7	0.38	5.9	6.2	4.0	0.057	2
40	3	3.7	0.44	6.0	6.6	4.0	0.103	2
44	3	2.2	0.37	5.5	8.4	28.0	-	-
45	3	3.0	0.37	6.1	8.7	8.0	-	-
50	3	4.4	0.46	5.4	15.2	3.0	0.083	3
51	3	4.1	0.53	5.6	9.2	9.0	-	-
59	3	4.6	0.38	5.5	7.5	17.0	-	-

NARDUS STRICTA

Topsoils

Site	n.	W/H	K_2O	pH	L.I.%	P_2O_5	Ex. Ca. %	n.
5	5	2.80	0.63	4.4	90.7	11.6	0.066	1
13	10	1.18	0.46	4.5	26.5	13.0	0.024	10
14	10	3.78	0.46	4.3	83.6	14.0	0.104	4
15	10	2.87	0.42	4.5	68.2	12.5	0.073	6
19	6	1.74	0.65	4.7	22.6	4.3	0.033	6
20	6	2.66	0.56	4.6	25.9	8.0	0.035	6
22	6	2.33	0.66	4.7	29.6	4.3	0.034	6
36	8	2.49	0.58	5.1	19.5	5.6	0.025	8
38	10	3.41	0.91	5.6	12.4	3.0	-	-
43	10	3.21	0.84	4.0	84.7	4.7	-	-
46	10	3.60	0.82	3.9	89.5	6.1	-	-
63	10	2.74	0.85	4.4	23.7	4.1	-	-

Subsoils

Site	n.	W/H	K_2O	pH	L.I.%	P_2O_5	Ex. Ca. %	n.
5	2	3.6	0.54	4.6	84.0	5.0	-	-
13	3	1.57	0.24	5.0	15.7	48.0	0.018	-
14	3	2.70	0.26	4.9	41.8	17.0	0.053	-
15	3	2.45	0.16	5.1	14.3	11.0	0.033	-
36	2	2.23	0.41	5.3	11.6	20.0	0.032	-
38	3	3.79	0.42	5.7	6.4	4.0	-	-
43	3	3.24	0.39	4.9	15.6	11.7	-	-
46	3	2.67	0.42	5.1	15.2	10.0	-	-
63	3	2.36	0.66	4.8	11.8	45.0	-	-

VACCINIUM

Topsoil

Site	n.	W/H	K_2O	pH	L.I.%	P_2O_5	Ex. Ca. %	n.
49	10	2.45	0.55	4.2	18.03	3.0	-	-

Subsoil

Site	n.	W/H	K_2O	pH	L.I.%	P_2O_5	Ex. Ca. %	n.
49	1	2.45	0.35	4.9	11.18	3.0	-	-

MOLINIA CAERULEA

Topsoils

Site	n.	W/H	K_2O	pH	L.I.%	P_2O_5	Ex. Ca. %	n.
10	10	3.76	0.67	4.5	73.9	12.2	0.076	10
11	10	3.55	0.67	4.3	89.0	11.2	0.051	7
12	10	2.65	0.41	4.4	67.2	15.3	0.066	8
17	11	2.84	0.89	4.3	85.7	14.6	0.077	9
37	10	3.91	0.57	4.3	78.4	5.4	-	-
41	10	2.45	0.80	4.4	43.9	7.6	-	-
42	10	3.43	0.89	4.2	86.2	4.7	-	-

Subsoils

Site	n.	W/H	K_2O	pH	L.I.%	P_2O_5	Ex. Ca. %	n.
10	3	3.43	0.23	5.3	10.8	7.0	0.019	-
11	3	3.77	0.24	4.6	16.4	5.0	0.028	-
12	3	2.13	0.18	4.7	18.8	20.0	0.018	-
17	4	1.69	0.20	5.2	22.3	10.0	0.028	-
37	2	2.27	0.51	5.1	21.1	12.0	-	-
41	3	2.55	0.49	5.0	13.1	12.0	-	-
42	3	2.69	0.36	5.1	19.3	9.0	-	-

DESCHAMPSIA FLEXUOSA

Topsoils

Site	n.	W/H	K_2O	pH	L.I.%	P_2O_5	Ex. Ca. %	n.
1	10	2.77	0.61	4.6	29.0	8.9	0.036	10
2	10	1.84	0.70	4.6	33.7	8.8	0.037	10
3	10	1.29	0.64	4.4	18.9	10.8	0.030	9
4	11	0.90	0.73	4.6	26.4	14.1	0.031	8
7	10	1.10	0.69	4.5	22.1	18.0	0.023	9
62	10	1.02	0.89	4.9	24.7	5.2	-	-

Subsoils

Site	n.	W/H	K_2O	pH	L.I.%	P_2O_5	Ex. Ca. %	n.
1	3	2.10	0.61	5.0	15.3	9.0	0.023	-
2	3	2.20	0.45	5.5	17.1	8.0	0.050	-
3	3	2.40	0.47	4.9	10.90	11.0	0.021	-
4	4	1.65	0.53	4.9	18.5	15.0	0.051	-
7	3	2.3	0.33	4.9	13.3	23.0	0.022	-
62	3	2.9	0.67	5.3	12.8	17.0	-	-

APPENDIX III:

COMPARISON OF RESULTS OF SOILS pH TAKEN WET AND DRIED

Number	pH-Wet	pH-Dry		
593	5.3	5.1*	MT	Site 51 A/F with tufty Ns.
594	5.3	4.7**	MT	
595	4.3	4.2	O	Site 52 Cv on 2" of peat
596	4.9	5.1*	MS	
597	4.2	4.2	O	
598	4.9	4.9	MS	
599	4.1	4.1	O	
600	4.5	4.8	MS	
601	4.2	4.1	O	
602	4.2	4.0*	O	
603	4.3	4.3	O	
604	4.1	4.1	O	
605	4.1	3.9*	O	
606	4.3	4.1*	O	
607	4.3	3.8*	O	

KEY

O	"Organic" soil over 40% organic matter
M	"Mineral" soil under 40% organic matter
T	Topsoil
S	Subsoil
A/F	Agrostis-fescue
Ns	Nardus stricta
Cv	Calluna vulgaris
Ev	Eriophorum vaginatum
Dc	Deschampsia caespitosa
Ag	Agrostis spp.
Df	Deschampsia flexuosa
Fo	Festuca ovina
*	Difference of between 0.2 and 0.5
**	Difference of between 0.6 and over.

Number	pH-Wet	pH-Dry			
608	4.0	3.9	O	Site 53	Cv on 3" of peat.
609	4.8	4.9	MS		
610	3.9	3.8	O		
611	4.7	4.7	MS		
612	3.8	3.6*	O		
613	4.6	4.5	MS		
614	4.0	4.0	O		
615	4.0	3.8*	O		
616	3.8	3.8	O		
617	3.8	3.8	O		
618	4.0	3.9	O		
619	3.8	3.9	O		
620	3.8	3.8	O		
621	3.8	3.8	O	Site 54	Cv on 3" of peat.
622	4.8	4.8	MS		
623	3.8	3.8	O		
624	4.8	4.9	MS		
625	3.7	3.8	O		
626	4.8	4.7	MS		
627	3.8	3.7	O		
628	3.9	3.5*	O		
629	4.0	3.8*	O		
630	3.8	3.6*	O		
631	3.9	3.6*	O		
632	3.8	3.6*	O		
633	3.8	4.0*	O		

Number	pH-Wet	pH-Dry		
634	4.1	4.0	0	Site 55 Cv on 2" of peat.
635	5.3	5.0*	MS	
636	4.2	4.0*	0	
637	5.7	5.5*	MS	
638	4.1	3.8*	0	
639	5.1	4.7*	MS	
640	4.4	4.0*	0	
641	4.0	3.8	0	
642	4.0	4.1	0	
643	4.3	4.0*	0	
644	4.2	3.6**	0	
645	3.9	3.5*	0	
646	4.0	4.0	0	
647	4.5	3.6**	0	Site 56 Cv on 18" of peat.
648	4.9	4.8	MS	
649	4.0	3.7*	0	
650	4.9	4.9	MS	
651	4.3	4.0*	0	
652	5.0	4.9	MS	
653	3.9	3.7*	0	
654	4.0	3.7*	0	
655	4.1	3.6*	0	
656	4.2	3.6**	0	
657	4.2	3.6**	0	
658	4.3	3.7**	0	
659	4.4	3.7**	0	

Number	pH-Wet	pH-Dry			
660	4.0	3.6*	O	Site 57	Cv - Ev on 4' of peat.
661	4.0	3.6*	OS		
662	4.0	3.8*	OS		
663	4.2	3.7*	OS		
664	3.8	3.4*	O		
665	3.8	3.5*	O		
666	4.0	3.5*	O		
667	3.9	3.5*	O		
668	3.8	3.6*	O		
669	3.8	3.5*	O		
670	3.8	3.6*	O		
671	3.8	3.9	O		
672	3.7	3.8	O		
673	4.1	3.8*	O	Site 58	Cv on 13" of peat.
674	5.5	5.0*	MS		
675	4.4	4.2*	O		
676	5.1	5.0	MS		
677	4.3	4.0*	O		
678	5.1	4.8*	MS		
679	4.2	3.9*	O		
680	4.1	3.8*	O		
681	4.4	4.1*	O		
682	4.5	4.4	O		
683	4.5	4.1*	O		
684	4.1	3.7*	O		
685	4.3	3.7**	O		

Number	pH-Wet	pH-Dry			
686	5.7	5.1**	M	Site 59	Dc - Ag on heavy loam.
687	6.2	5.5**	MS		
688	5.8	5.3*	M		
689	6.0	5.5*	MS		
690	6.0	5.2**	M		
691	6.0	5.6*	MS		
692	5.6	5.2*	M		
693	5.8	5.3*	M		
694	6.0	5.4**	M		
695	5.8	5.5*	M		
696	5.7	5.2*	M		
697	5.6	5.4*	M		
698	5.5	5.2*	M		
699	4.0	3.9	O	Site 60	Cv on 2" of peat.
700	4.6	4.7	MS		
701	3.8	3.8	O		
702	4.6	4.7	MS		
703	3.9	3.8	O		
704	4.6	4.7	MS		
705	4.1	3.9*	O		
706	4.3	4.3	O		
707	3.7	3.7	O		
708	3.8	3.6*	O		
709	3.9	4.0	O		
710	3.9	4.1*	O		
711	3.7	3.8	O		

Number	pH-Wet	pH-Dry			
712	3.8	3.8	O	Site 61	Cv - Ev on 6' of peat.
713	3.8	3.9	OS		
714	4.0	3.9	OS		
715	4.0	3.7*	OS		
716	3.7	3.8	O		
717	3.9	4.2*	O		
718	3.8	4.3*	O		
719	3.9	4.0	O		
720	3.7	3.8	O		
721	4.0	3.8*	O		
722	3.9	3.9	O		
723	3.8	3.8	O		
724	3.6	3.8*	O		
725	5.1	5.0	M	Site 62	Df - Fo on light loam.
726	5.5	5.3*	MS		
727	5.1	4.9*	M		
728	5.5	5.4	MS		
729	5.2	5.0*	M		
730	5.3	5.3	MS		
731	5.0	4.9	M		
732	5.0	5.0	M		
733	5.0	4.8*	M		
734	5.0	5.1	M		
735	4.9	4.8	M		
736	5.0	5.0	M		
737	5.1	4.8*	M		

Number	pH-Wet	pH-Dry		
738	4.9	4.5*	M	Site 63 Ns - Ag on medium loam.
739	5.6	5.2*	MS	
740	4.7	4.4*	M	
741	5.3	4.7**	MS	
742	4.8	4.5*	M	
743	5.1	4.4**	MS	
744	4.7	4.4**	M	
745	4.7	4.5*	M	
746	4.6	4.3*	M	
747	5.1	4.3**	M	
748	4.8	4.5*	M	
749	4.6	4.2*	M	
750	4.5	4.3*	M	

APPENDIX IV.

APPENDIX IV.

Methods of Soil Analysis

Water/Humus Ratio.

As a quantitative method of estimating the "wetness" of the soil in which the various plant communities grew, a humidity coefficient, or W/H factor, based on the procedure of Crump, 1913, was estimated for each soil sample.

Between 14-16 g. of wet soil were weighed accurately as soon after sampling as possible, and always within four hours. Before being weighed, the wet soil was roughly sieved. The weighed portion was then transferred to a paper tray where it remained for at least a fortnight till it was air-dry; peaty soils however, were allowed to remain for a month. Crump advocated that the drying process should take place at a constant temperature of 15 degrees Centigrade, but the writer, had no facilities for carrying out this process. The air-dry portion was then weighed and incinerated in a butane-fired muffle. After weighing the incinerated residue, the amount of water lost in air-drying and the amount of organic material lost on incineration, were obtained by subtraction. These figures were then expressed as a percentage of the air-dry weight of the soil. By dividing the percentage of water lost by the percentage of organic matter, the W/H factor was calculated. The coefficient /

coefficient thus found expressed the number of parts of water per part of humus lost in air-drying.

It should be pointed out that the figures obtained by this method cannot be compared directly with those obtained by Crump. The difference is that Crump, having weighed his air-dry soil which gave an estimate of physiological water, further dried his soils at 100 degrees Centigrade. This removed all the remaining water held in the colloidal complex. Again, the writer had no facilities for this determination. Crump's humus percentages, expressed as a percentage of the oven dry weight of the soil will thus be lower than those obtained by the writer, while his water percentage and his coefficients will be higher. An experiment was therefore carried out to ascertain whether with the same soil and using the amended method there was any significant variation in W/H factor.

Five soils were obtained of varying organic matter content and three samples were estimated for each by the amended method. The results are shown below:

		Humus %	Water %	W/H
Soil 1	a	33.2	107.0	3.22
	b	33.2	106.0	3.18
	c	35.1	113.0	3.22
Soil 2	a	10.5	14.5	1.37
	b	11.4	15.5	1.36
	c	10.7	13.7	1.28

/

		Humus %	Water %	W/H
Soil 3	a	31.3	58.6	1.87
	b	31.8	57.8	1.82
	c	32.7	52.2	1.75
Soil 4	a	69.7	189.0	2.71
	b	66.9	179.0	2.67
	c	70.2	192.0	2.74
Soil 5	a	74.2	230.0	3.10
	b	74.2	227.0	3.07
	c	74.5	227.0	3.02

The results obtained show, for each soil tested, a close similarity in W/H factor, and the writer feels justified in assuming the coefficient as a valid indicator of soil "wetness".

Crump has shown that the ratio held good in soils where organic matter was high (over 15%). In such soils, he considered that the organic matter complex held all but a very small proportion of the soil water. Below 15% organic matter, the amount of water held by mineral and clay particles increased greatly. It will be appreciated that the W/H factor does not apply when considerable amounts of colloidal clay are present.

Exchangeable Calcium

Exhangeable Calcium was estimated according to the method of Rice Williams, 1928. 20 g. of dried, sieved soil were placed in a beaker with 200 ccs. of N acetic acid. After being stirred, the soil and acid were allowed to stand for 24 hours. Owing to the high percentage of organic matter in the bulk of the samples, it was considered advisable to allow adequate time for the leaching of calcium from the soil. /

soil. The soil and acid were then filtered and the soil leached with N acetic acid until there were approximately 350 ccs. of filtrate. This filtrate was then made up to 400 ccs with distilled water and an aliquot of 200 ccs taken. To the aliquot were added 10 ccs of 0.88 Ammonia and 5 g. of Ammonium chloride. This solution was boiled and 25 ccs of 4% ammonium oxalate added. After boiling for 5 minutes, the solution was allowed to cool overnight. The cold solution was then filtered and the precipitated calcium oxalate was washed with hot distilled water. When the calcium oxalate had been washed off the filter paper, it was dissolved by adding 10 ccs. of 5N H_2SO_4 and estimated, when hot, by titrating with N/10 potassium permanganate. The figures for exchangeable calcium are given as a percentage of the original air dry soil.

Hydrogen ion Concentration

For the estimation of soil acidity, a Muirhead pH meter was used which had been standardised with buffers of pH 4 and 9. As before, the soil was air dried and sieved. To one part by volume of soil, 2.5 parts of distilled water were added. The mixture was stirred, left for 10 minutes, then stirred again when the pH was estimated from the meter.

Phosphates:

Phosphates were estimated by the Kirssanov method. 5 g. of the airdried and sieved soil were shaken with 10 ccs of 0.2 N HCl, and allowed to stand for 10 minutes. The mixture was filtered and 5 cms. of the filtrate were added to 15 ccs. of Molybdate solution. To this 1 cc of Stannous chloride solution was added and the resulting blue colour was compared with a known standard in a colorimeter. The results are expressed in mgms per 100 g of air-dry soil.

Potassium:

Potassium was estimated by means of the Aspergillus niger method. 2.5 g. of air-dried and sieved soils were added to 30 ccs. of nutrient solution which had been inoculated with a culture of Aspergillus niger. The whole was incubated for 5 days at 37 degrees Centigrade and the resulting mycelium weighed. After correcting the weight from a control grown in nutrient solution without soil, the weight of mycelium was related to the amount of available potassium in the soil. A mycelium weight of less than 0.25 g. was rated low, 0.35 was medium and over 0.46 was high. In the normal routine analysis, these values have been accepted for arable soils.